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Standardisation of unified design of locomotives of the German Railways, (1)

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Figs. 1 to 41, pp. 97 to 114.

I — Historical development

The problem of standardising rolling-stock has long engaged the attention of the principal railway administrations in Germany. As regards freight vehicles, the question has been solved completely. On its creation nearly 20 years ago, the German Wagon Association (D. W. V. = Deutscher Wagen Verband) adopted certain types of wagons which were standardised. Out of some 635 000 wagons owned by the Reichsbahn in 1924, nearly 370 000 or about 58 % were as the result of standardised type. On the other hand, the specifications for carriages not having been standardised, Prussia, Bavaria, Saxony, Wurtemberg, Baden, Mecklenburg, and Oldenburg provided only for unification of overall dimensions (fig. 1) and of the technical conditions of construction. The interior arrangement and the details of construction varied with local customs and the traditions of the various systems. A heterogeneous stock of carriages was thus accumulated,

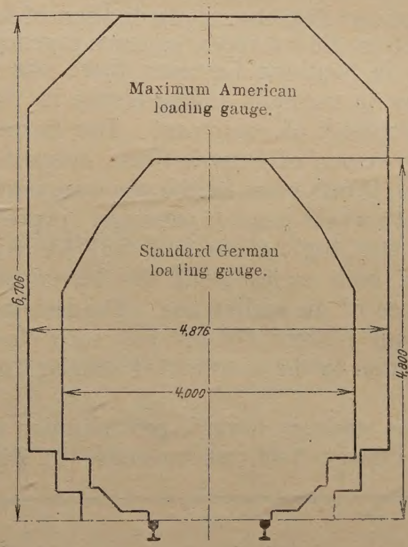


Fig. 1. — Comparison of American and German loading gauges.

and it was only in 1921 that there were placed in service the first standardised coaches, steel-built, two-axle, fourth-class carriages. In 1924 the German railways

(1) Translated from the French.

possessed about 3 700 of these standardised vehicles, or about 4.7 %, out of a total of 79 000 carriages. This number, as well as that of the modified types and series, has since increased, many new coaches having been ordered for express (bogie stock), fast and stopping trains.

* * *

The question of standardising locomotives offered much greater difficulty. Before the war there was considerable divergence between the viewpoints of the railway administrations in the German States. Differences between the gradient sections of the lines, and between traffic conditions in various districts, had their influence upon locomotive design, so that in pre-war days the standardisation of locomotives did not appear of much urgency. Also in Southern Germany there was a desire to maintain independence in the development of equipment. The former State system of Prussia-Hesse, operating about 13 000 miles before the war, developed a whole range of passenger (express and stopping), goods and tank locomotives, each series being the logical sequence of an earlier one. The less important systems did not pay such close attention to the question of standardisation.

The tendency towards centralisation in the railway field, recommended by Bismarck, after the war of 1870-1871, when Prussia began to play a predominant part in the Reich, has increased since the defeat of the Empire in 1918. The « Imperialisation » of the former State railway systems by cession of the lines to the Reich, provided for by the Constitution of Weimar, and brought into force on 1 April 1920, has led inevitably to an *administrative concentration* favouring *organic reform* and *technical consolidation.* The individualistic buttresses of the south have been swept away, and the administrative and technical outlooks have been brought into line with those of Berlin based on the Prussian system, which constitutes nearly half the entire network. The Prussian lines, owing to the easier country, were better built and more completely fitted with technical equipment, and consequently the formation of a single railway system in Germany under the control of Prussia became an accomplished fact (fig. 2).

* * *

The policy of reducing the number of types of locomotives, with a view to securing the advantages of homogeneity, has been followed for a long time past by the German railways. The Prusso-Hessian system, the largest in Germany, for example, has had its recent locomotives built to the following broad series :

SERVICE.	TYPE.	Year of construction of first locomotive.	SERIES	Number of locomotives built.
Fast and express passenger.	4-6-0	1914, Vulcan.	S_{10}	...
Slow passenger	4-6-0	1914, Schwartzkopf.	P_8	2 500
Goods	0-8-0	1910, Schichau	$G_8{}^1$	2 300
—	0-10-0	1910, Henschel.	G_{10}	1 700
—	2-10-0	1917, Henschel.	G_{12}	1 100

Fig. 2. — Map of the main lines of the German State Railway Company.

Explanation of French terms : Mer Baltique = Baltic Ocean. — Mer du Nord = North Sea.

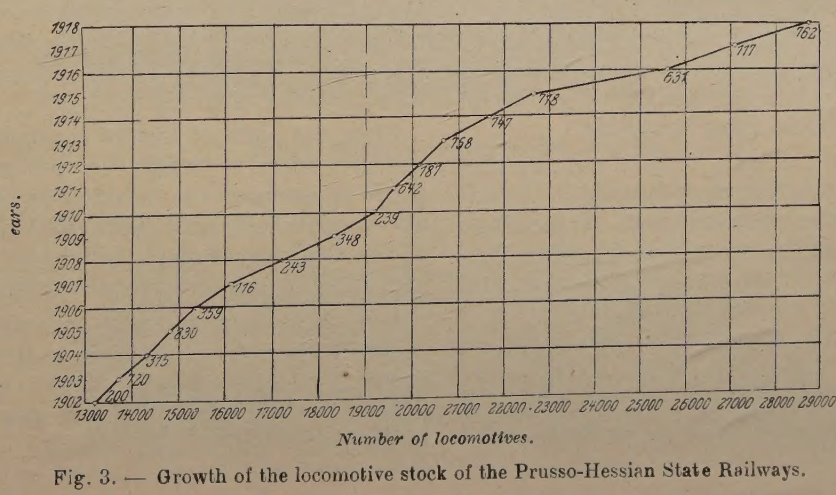


Fig. 3. — Growth of the locomotive stock of the Prusso-Hessian State Railways.

The above diagram (fig. 3) shews the annual numerical growth of the stock during the period 1902-1918.

In 1920, when the Reich took over the railways, there were 210 different series of locomotives and the need for *unification* was immediately apparent. The different classes of German locomotives did not readily lend themselves to a quick standardisation. It was difficult, indeed, to unify the equipment rapidly, adopting existing engines as standards, because the latter, though often excellent in themselves, had not been designed with standardised components. It was necessary, therefore, to create new series to meet the variable conditions of service on the different lines. At the same time, work in the shops, recently put on an industrial and commercial basis, had to be reorganised in order that certain shops might specialise on the maintenance of particular types of locomotives, thus reducing the stock of spares.

A special Commission was appointed by the Minister of Transport to determine the new types of locomotives required for the German State Railways. This Commission, composed of competent Mechanical and Running Department Engineers came to the conclusion that complete new designs would have to be prepared using standard parts throughout which would be completely interchangeable.

We have already pointed out the preponderant influence of Prussia in the administrative reorganisation of the State railways at the expense of the other German systems as a result of the extent and experience of the Prussian system, and particularly owing to its stock being the largest.

During the design of the new types of standard locomotives the supremacy of Prussia became more clearly marked. Everything built since 1920 has been but the development of the old types of Prusso-Hessian locomotives.

* * *

The other railways also possessed powerful locomotives, though these were comparatively few, owing to the smaller mileage of the lines. Table I gives interesting particulars of some of the powerful locomotives owned by the railways of Saxony (figs. 4 and 5), of Bavaria (figs. 6 and 7), of Wurtemberg (fig. 8), of Baden (figs. 9 and 10) and of Oldenburg (fig. 11), on the eve of their transfer to the Reich.

It will thus be seen that the railways of the South German States owned very powerful high-speed locomotives, such as the *Pacific* types of Bavaria (fig. 6), Baden (figs. 9 and 10), Wurtemberg (fig. 8) and Saxony (fig. 4). These lines were also the first in Germany to introduce powerful types of locomotives : the Saxon Railways built the first *Mikado* (fig. 5) for express trains, the most powerful locomotive at that time, whilst the Wurtemberg lines had the first twelve-wheel coupled goods engine of the « Centipede » type (fig. 8) and the Bavarian lines the most powerful tank engine (fig. 7).

From the point of view of construction and cleverness of design, as well as regards appearance, the locomotives of the above-mentioned lines were well ahead of the Prussian engines, which are very heavy and massive in general appearance.

For comparison the same information (table II) is given for the Prusso-Hessian locomotives (figs. 12 to 23) so as to bring out certain differences we are about to analyse.

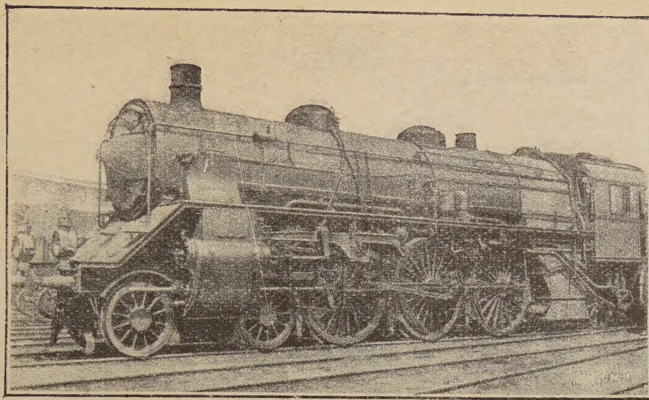


Fig. 4. — Express *Pacific* locomotive of the Saxon Railways.

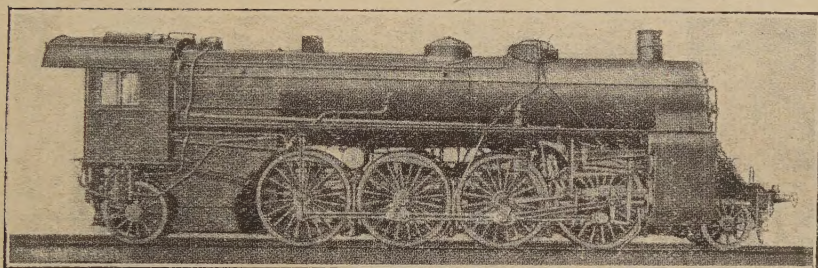


Fig. 5. — Express *Mikado* locomotive of the Saxon Railways.

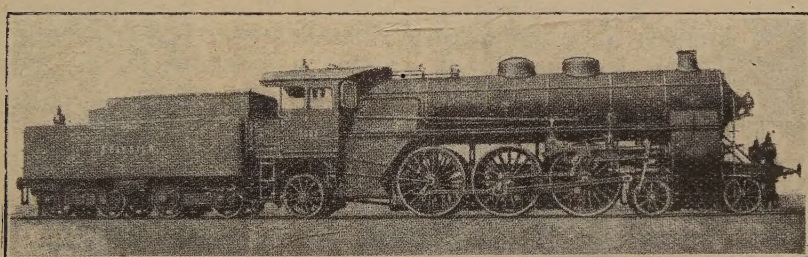


Fig. 6. — Express *Pacific* locomotive of the Bavarian Railways.

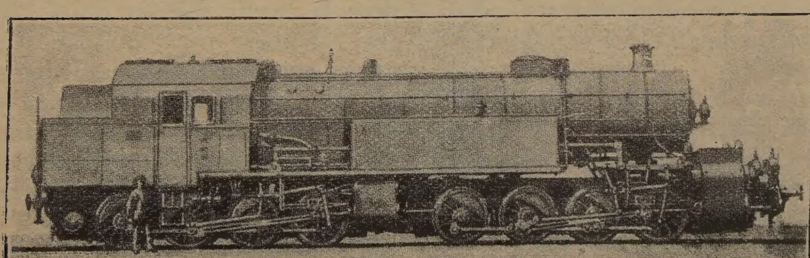


Fig. 7. — Powerful tank locomotive, *Mallet* type, for banking on heavy gradients on the Bavarian Railways.

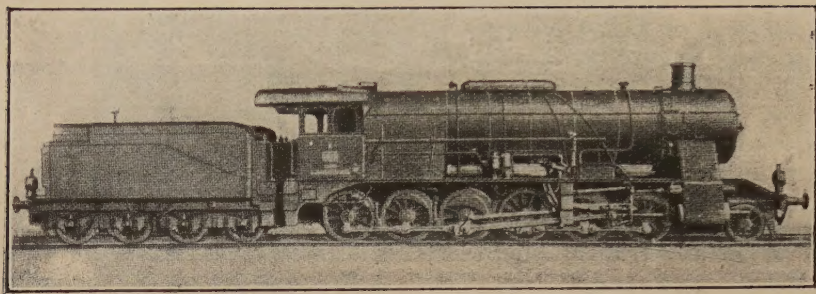


Fig. 8. — Powerful 12-coupled goods locomotive of the Wurtemberg Railways.

II. — **Present tendencies.**

In the general working of railways the budget for rolling stock and locomotive running forms the greatest part of the general expenditure. Almost half this budget is absorbed by capital charges representing the capital expended in building new stock, both traction and rolling, and the cost of their maintenance. For this reason it is extremely important to reduce as far as possible the capital thus sunk, and to diminish those initial expenses which increase continually with the growth of traffic.

The construction of locomotives depends on the same economic laws as that of other industrial products. The unit cost decreases as the number ordered increases, and further economies can be effected by designing components so that they may be interchangeable on different types of machines.

This is the object of the *Scientific organisation of labour in the field of technical standardisation.*

Soon after the German Office for Industrial Standardisation (N. D. I. = *Normen-Ausschuss der Deutschen Industrie*) was started, the locomotive builders agreed to form the Section for the General Standardisation of Locomotives (A. L. N. A. = *Allgemeiner Locomotiv Normen-Ausschuss*). The object the « Alna » has followed since its formation has been to study from the point of view of economy, by means of a close collaboration between the industry affected and the representatives of the State Railways, the designs of spare parts and establish the various standardised series of parts (« Normalien »). The principles of interchangeability have been strictly observed : they formed the principal objects of the investigation.

In order to carry the standardisation of parts and machining methods further forward, a special section was formed soon after under the tittle « Elna » (Engerer-Lokomotiv-Normen Ausschuss), between the Mechanical Engineering Industry and the State Railways who closely collaborated so as to collate the *experience* acquired *in service* with the technical *requirements as to machining and erection.*

The mass production of locomotive parts is hardly possible unless the accuracy of these parts is such that they can be assembled without fitting so as to be fully interchangeable during repairs. This made it necessary to determine the minimum and maximum dimensions very closely : *to define the gauges and tolerances.*

The principal work the « Elna » had to

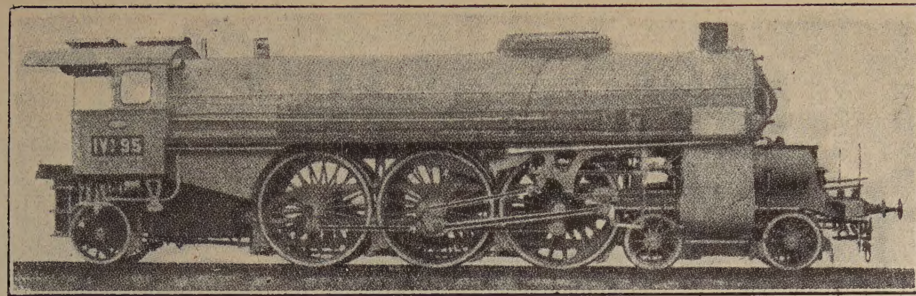


Fig. 9. — Express *Pacific* locomotive (type IV*h*) of the Baden Railways.

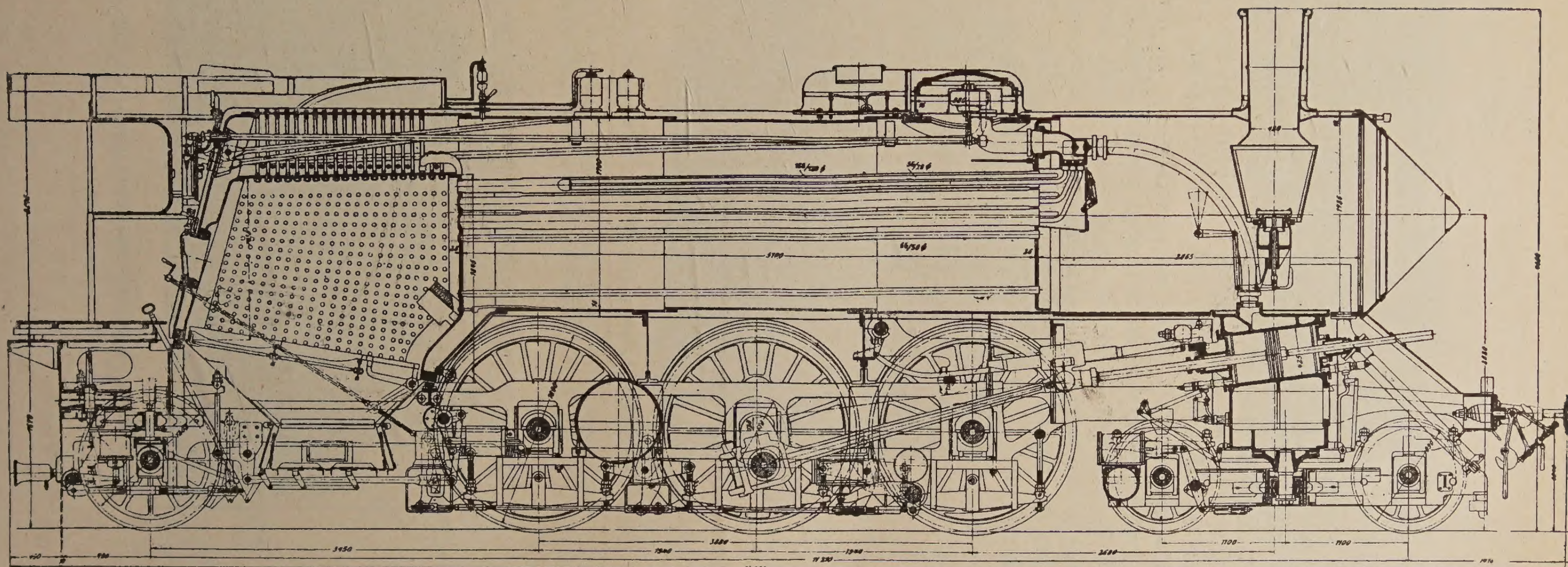


Fig. 10. — Longitudinal section of the type IV*f* *Pacific* locomotive of the Baden Railways.

do was to examine and define the limiting tolerances required for erection « without fitting » and which are essential for the subsequent interchangeability of the parts.

Two systems of standardisation are in use : the basis can be either the « *pin* » or the « *hole* ». The « Elna » decided upon the « *hole* ».

The work of the « Elna » was so arranged that the design of the different parts and the different processes were distributed to the works collaborating with it which specialised in one or other branch of production.

The parts so designed were considered by the other manufacturers or by the State Railways, and were then again discussed first of all by the « Elna » and then by the « Alna ». As regards future series of standard locomotives for the State Railways, the General Management of the State Railways has the final decision.

In order to *restrict* the *number* and *kind*, of the different *components* it was necessary to design them symmetrically wherever possible, thus allowing for either right or left-hand mounting, and also providing for *interchangeability* be-

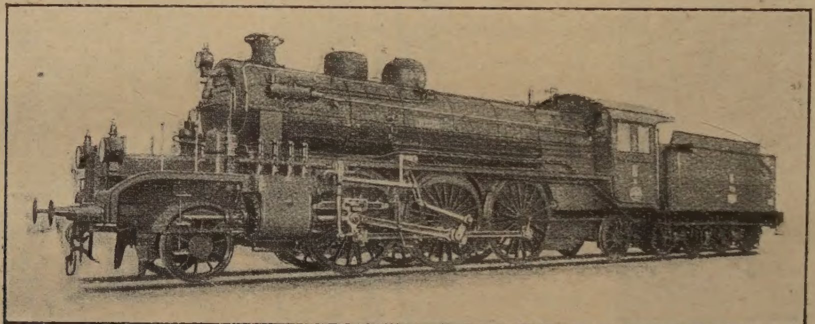


Fig. 11. — Express *Prairie* type locomotive of the Oldenburg Railways.

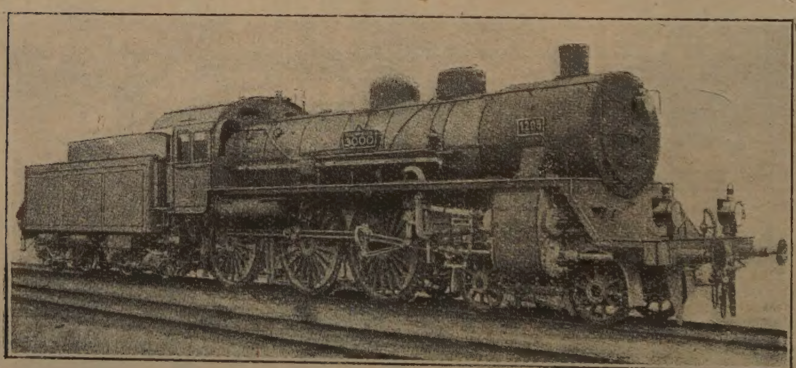


Fig. 12. — Express *Ten wheel* type locomotive of the Prussian Railways.

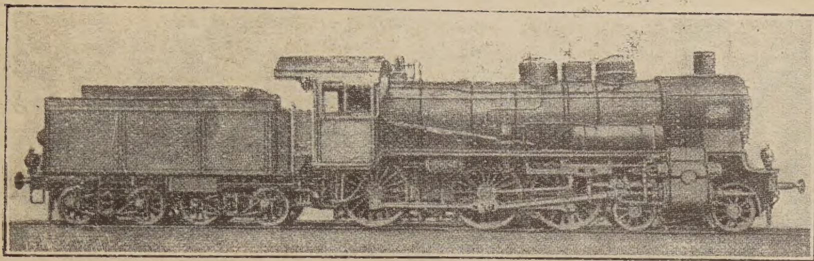


Fig. 13. — Passenger *Ten wheel* type locomotive of the Prussian Railways.

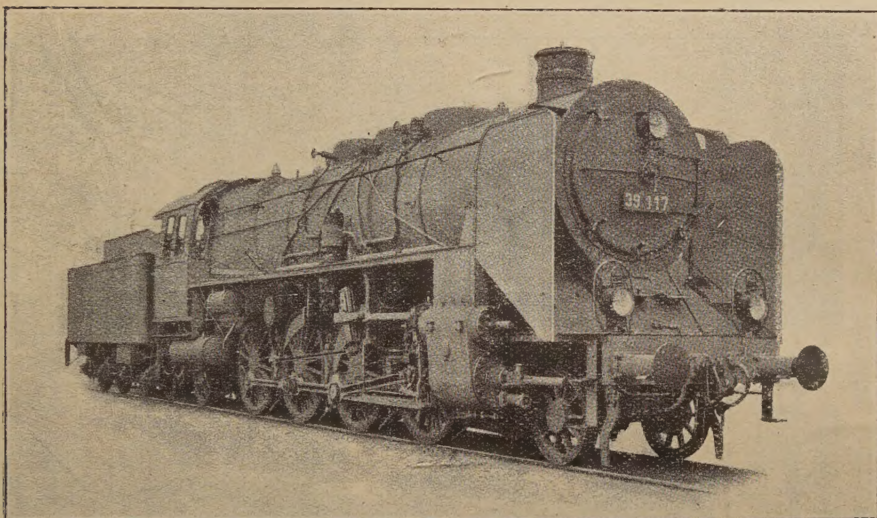


Fig. 14. — New standard passenger *Mikado* locomotive for express trains on the German Railways (non standard details).

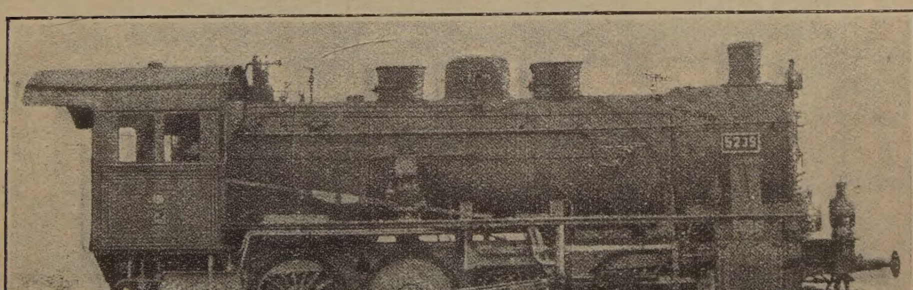


Fig. 15. — Eight coupled goods engine on the Prussian Railways.

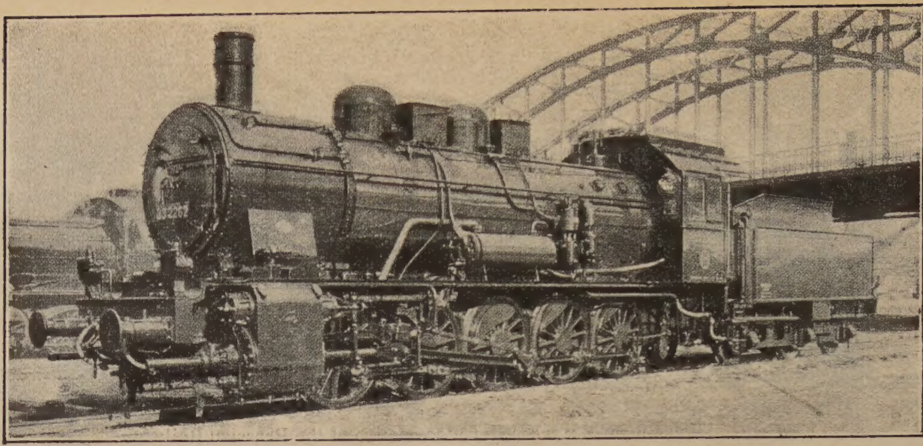


Fig. 16. — Superheated ten coupled goods engine of the Prussian Railways.

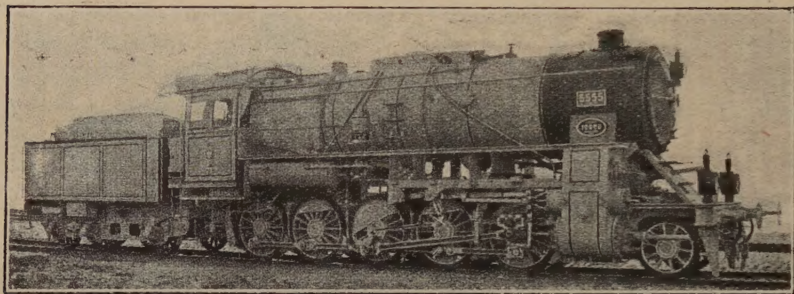


Fig. 17. — *Decapod* goods engine of the Prussian Railways.

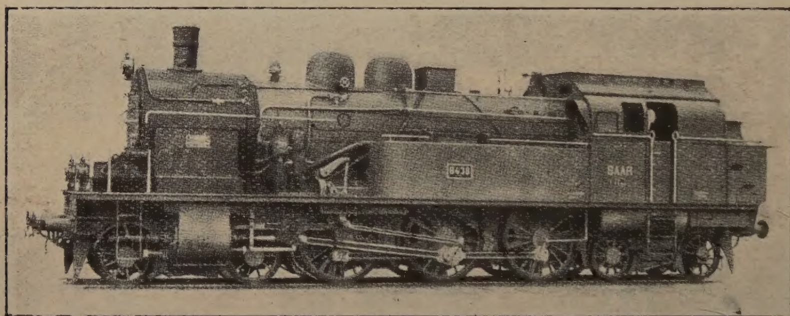


Fig. 18. — Passenger *Baltic* tank engine of the Prussian Railways.

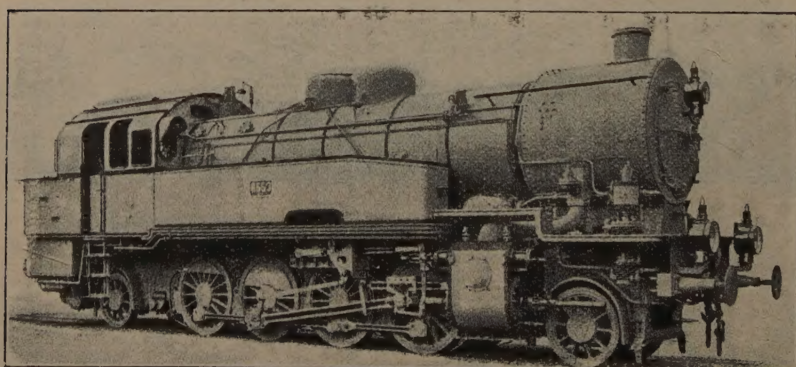


Fig. 19. — Goods *Mikado* tank engine of the Prussian Railways.

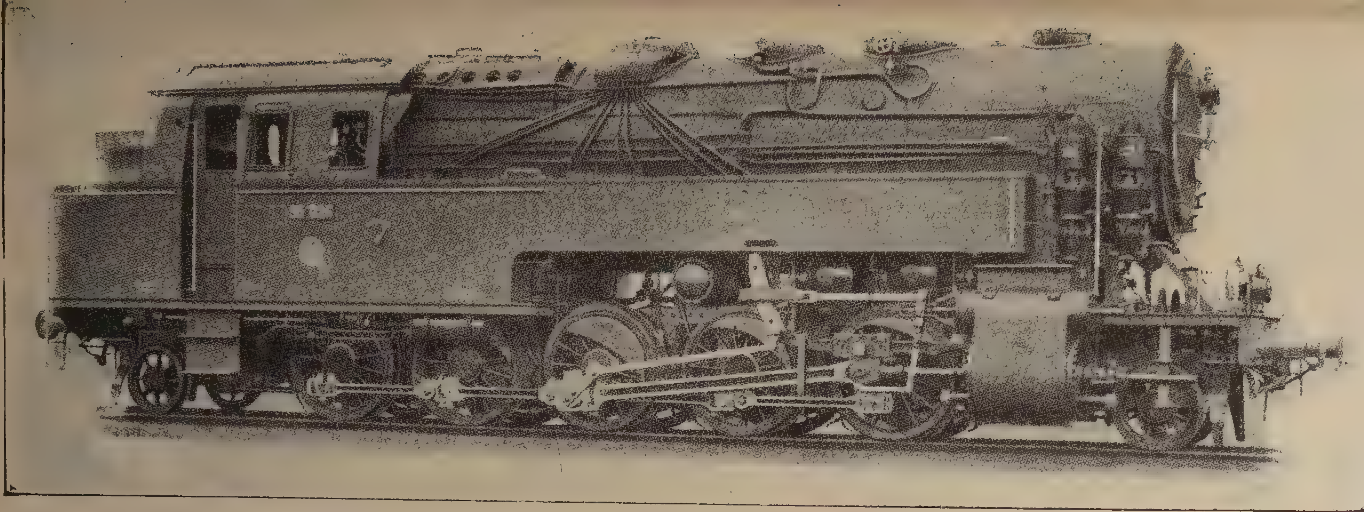


Fig. 20.— Powerful mixed traffic standard *Santa-Fe* type tank engine of the German Railways (non standard details).

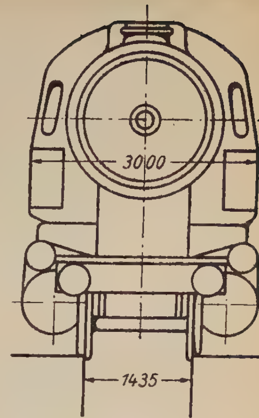


Fig. 22.
End on view. Leading end.

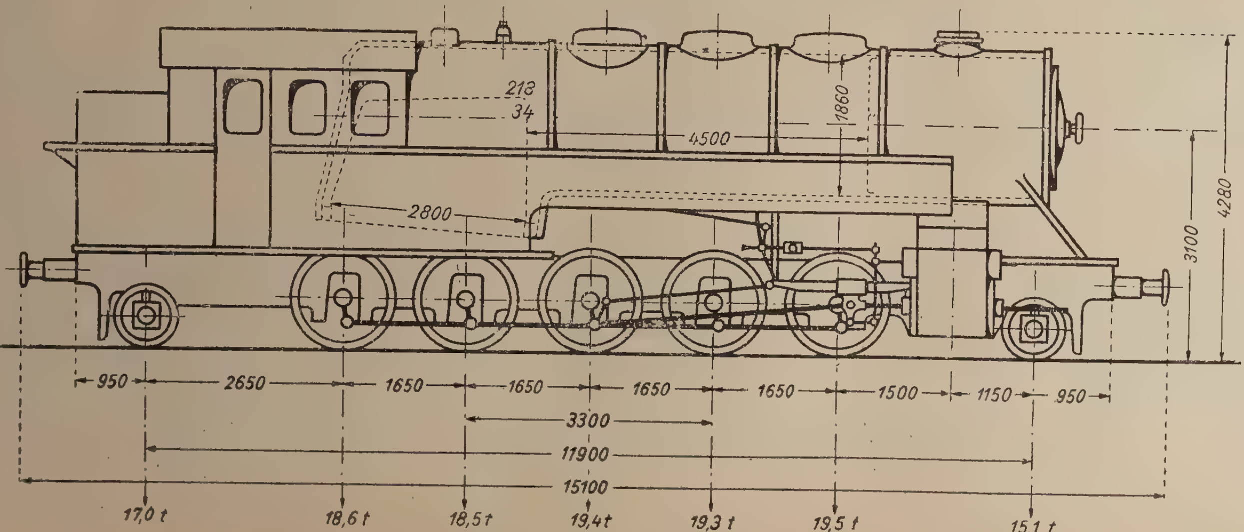


Fig. 21. — Elevation.

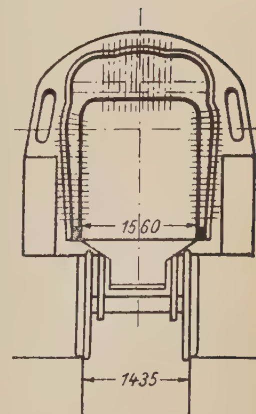


Fig. 23.
Section through firebox.

Table I.

SYSTEM.	TYPE.	SERIES.	Year and builder of first engine.	Maximum speed, in kilom. (miles) per hour.	Boiler pressure, kgr. per cm² (lb. per sq. inch).	Grate area, in square metres (in square feet).	Cylinders, diameter, in millimetres (in inches).	Stroke, in millimetres (in inches).	Driving wheels, diameter, in millimetres (in feet and inches).	Weight: Empty. Metric (English) tons.	Weight: In working order. Metric (English) tons.	Weight: Adhesion (A) Metric (English) tons.	Metric tons on 1 m. of length (English tons on 1 foot of length).	Power coefficient: Absolute $C_1 = \frac{d^2 s}{D}$	Power coefficient: Relative $C_2 = \frac{C_1}{A}$
Passenger traffic.															
Bavaria	4-6-2	S 3/6	1912, Maffei.	120 (74.6)	15 (213)	4.50 (48.44)	Compound 2 × 425/650 (16 3/4 and 25 5/8)	670 (26 3/8)	2 000 (6' 6 3/4")	81.6 (80.31)	89.5 (88.09)	48.0 (47.24)	6.95 (2.085)	1 415	28.9
Baden	4-6-2	IVh	1919, —	100 (62.1)	15 (213)	5.00 (53.82)	Compound 2 × 440/680 (17 5/16 and 26 3/4)	680 (26 3/4)	2 100 (6' 10 5/8")	87.5 (86.12)	97.0 (95.47)	53.4 (52.56)	6.93 (2.079)	1 497	28.2
Wurtemberg	4-6-2	C	1908, Esslingen.	100 (62.1)	15 (213)	3.95 (42.52)	Compound 2 × 420/620 (16 1/2 and 24 3/8)	612 (24 1/16)	1 800 (5' 10 7/8")	79.5 (78.24)	87.8 (86.41)	48.0 (47.24)	6.87 (2.061)	1 305	27.9
Saxony	4-6-2	XVIII H	1917, Hartmann.	100 (62.1)	14 (192)	4.50 (48.44)	Simple 3 × 500 (19 11/16)	630 (24 3/8)	1 905 (6' 3")	84.4 (83.07)	93.5 (92.02)	50.7 (49.90)	7.03 (2.109)	1 242	24.5
—	2-8-2	XX HV	1918, —	100 (62.1)	15 (213)	4.50 (48.14)	Compound 2 × 480/720 (18 7/8 and 28 3/8)	630 (24 3/8)	1 905 (6' 3")	90.3 (88.87)	99.9 (98.32)	68.6 (67.52)	7.18 (2.154)	1 710	25.2
Oldenburg	2-6-2	S_{10}	1917, Hanomag.	100 (62.1)	14 (199)	3.00 (32.29)	Simple 2 × 580 (22 13/16)	630 (24 3/8)	1 980 (6' 6")	98.9 (97.34)	73.9 (72.73)	45.4 (44.68)	6.04 (1.812)	1 070	23.0
Freight traffic.															
Bavaria	0-10-0	G 5/5	1920, Maffei.	60 (37.3)	16 (228)	3.70 (39.83)	Compound 2 × 450/690 (17 11/16 and 27 1/8)	610/640 (24/25 1/4)	1 270 (4' 2")	75.8 (74.60)	83.4 (82.08)	83.4 (82.06)	6.82 (2.046)	2 400	29.1
Baden	2-8-0	VIIIc	1908, —	65 (40.4)	16 (228)	3.75 (40.36)	Compound 2 × 395/635 (15 9/16 and 25)	640 (25 1/4)	1 350 (4' 5 1/8")	70.4 (69.29)	77.1 (75.88)	65.5 (64.47)	6.74 (2.022)	1 910	28.3
Wurtemberg	2-12-0	K	1918, Esslingen.	60 (37.3)	15 (213)	4.20 (45.21)	Compound 2 × 500/750 (19 11/16 and 29 1/2)	650 (25 5/8)	1 350 (4' 5 1/8")	98.2 (96.65)	108.0 (106.29)	94.6 (93.11)	7.59 (2.277)	2 781	29.7
Saxony	2-10-0	XIII H	1919, Hartmann.	65 (40.4)	14 (199)	3.00 (32.29)	Simple 3 × 570 (22 7/16)	660 (26)	1 400 (4' 7 1/8")	86.8 (85.43)	96.5 (94.98)	82.8 (81.49)	7.74 (2.322)	2 298	27.7
Mixed traffic.	Tank engines.														
Bavaria	2-6-4	Pt 3/6	1911, Krauss.	90 (55.9)	13 (185)	2.31 (25.19)	Simple 2 × 530 (20 7/8)	560 (22)	1 500 (4' 11")	69.7 (68.60)	92.8 (91.22)	47.4 (46.65)	6.89 (2.067)	1 049	22.1
—	0-8 + 8-0	Gt 2 × 4/4	1914, Maffei.	50 (31.1)	15 (213)	4.25 (45.74)	Compound 2 × 520/800 (20 1/2 and 31 1/2)	640 (25 1/4)	1 216 (3' 11 7/8")	101.7 (100.09)	127.6 (125.58)	127.6 (124.58)	7.24 (2.172)	3 365	27.5
Baden	2-6-2	VIc	1914, Karlsruhe.	90 (55.9)	12 (171)	2.00 (21.53)	Simple 2 × 540 (21 5/16)	640 (25 1/4)	1 600 (5' 3")	60.2 (59.25)	78.4 (77.16)	49.9 (49.07)	6.17 (1.851)	1 166	24.7
Saxony	0-6 + 6-0	XV HT	1916, Hartmann.	70 (43.8)	15 (213)	2.50 (26.91)	Compound 2 × 440/680 (17 5/16 and 26 3/4)	630 (24 3/8)	1 400 (4' 7 1/8")	74.6 (73.42)	92.2 (90.74)	92.2 (90.74)	6.30 (1.890)	2 082	22.6
—	2-6-2	XIV HT	1918,	75 (46.6)	12 (171)	2.30 (24.76)	Simple 2 × 550 (21 11/16)	600 (23 5/8)	1 590 (5' 2 5/8")	64.2 (63.19)	82.2 (80.90)	49.4 (48.62)	6.62 (1.986)	1 141	23.1
—	0-10-0	XI HT	1918, —	45 (28.0)	12 (171)	2.27 (24.43)	Simple 2 × 620 (24 3/8)	630 (24 3/8)	1 260 (4' 1 5/8")	61.0 (60.03)	77.3 (76.08)	77.3 (76.08)	6.33 (1.899)	1 923	24.2

Table II.

SYSTEM.	TYPE.	SERIES.	Year and builder of first engine.	Maximum speed, in kilom. (miles) per hour.	Boiler pressure, kgr. per cm² (lb. per sq. inch).	Grate area, in square metres (in square feet).	Cylinders, diameter, in millimetres (in inches).	Stroke, in millimetres (in inches).	Driving wheels, diameter, in millimetres in feet and inches.	Weight — Empty. Metric (English) tons.	Weight — In working order. Metric (English) tons.	Weight — Adhesion (A). Metric (English) tons.	Metric tons on 1 m. of length (English tons on 1 foot of length).	Power coefficient. Absolute $C_1 = \frac{d^2s}{D}$	Power coefficient. Relative $C_2 = \frac{C_1}{A}$
Express trains. Prussia-Hesse . .	4-6-0	S_{10}	1910, Schwartzkopf.	110 (68.3)	14 (199)	2.86 (30.78)	Simple 4 × 430 (16 15/16)	630 (24 3/4)	1 980 (6′ 6″)	66.9 (65.84)	77.2 (75.92)	50.9 (50.10)	7.24 (2.172)	1 177	22.7
	4-6-0	$S_{10}{}^1$	1914, Henschel.	110 (68.3)	15 (213)	3.18 (31.23)	Compound 2 × 400/610 (15 3/4 and 24	660 (26)	1 980 (6′ 6″)	75.7 (74.50)	83.1 (81.79)	53.2 (52.36)	6.98 (2.091)	1 240	23.8
	4-6-0	$S_{10}{}^2$	1914, Vulcan.	110 (68.3)	14 (199)	2.86 (30.78)	Simple 3 × 500 (19 11/16)	630 (24 3/4)	1 980 (6′ 6″)	73.8 (72.63)	80.9 (79.62)	53.4 (52.56)	6.76 (2.028)	1 193	22.6
Passenger trains. Prussia-Hesse . .	4-6-0	P_8	1914, Schwartzkopf.	100 (62.1)	12 (171)	2.64 (28.41)	Simple 2 × 575 (22 5/8	630 (24 3/4)	1 750 (5′ 9″)	70.7 (69.58)	78.2 (76.96)	51.6 (50.78)	6.88 (2.064)	1 190	23.0
	2-8-2	P_{10}	1922, Borzig.	120 (74.6)	14 (199)	4.00 (43.06)	Simple 3 × 520 (20 1/2)	660 (26)	1 750 (5′ 9″)	100.4 (98.81)	110.4 (108.66)	75.7 (74.50)	7.59 (2.277)	1 530	22.5
Goods trains. Prussia-Hesse . .	0-8-0	$G_8{}^1$	1912, Schichau.	55 (34.2)	14 (199)	2.66 (28.63)	Simple 2 × 600 (23 5/8)	660 (26)	1 350 (4′ 5 3/16″)	62.2 (61.22)	69.9 (68.80)	69.9 (68.80)	6.33 (1.899)	1 760	25.9
	0-10-0	G^{10}	1910, Henschel.	60 (37.3)	12 (171)	2.63 (28.31)	Simple 2 × 630 (24 3/4)	660 (26)	1 400 (4′ 7″)	69.6 (68.50)	76.6 (75.39)	76.6 (75.39)	6.48 (1.944)	1 870	26.2
	2-10-0	G_{12}	1917, —	65 (40.4)	14 (199)	3.90 (41.98)	Simple 3 × 570 (22 7/16)	660 (26)	1 400 (4′ 7″)	85.4 (84.05)	95.7 (94.19)	82.5 (81.20)	7.56 (2.268)	2 300	28.8
	Tank engines.														
Mixed trains. Prussia-Hesse . .	4-6-4	T_{18}	1912, Vulcan.	90 (55.9)	12 (171)	2.44 (26.26)	Simple 2 × 560 (22)	630 (24 3/4)	1 650 (5′ 5″)	83.2 (81.89)	105.0 (103.34)	51.1 (50.29	7.11 (2.133)	1 200	26.4
	2-8-2	T_{14}	1913, Union.	65 (40.4)	12 (171)	2.56 (27.56)	Simple 2 × 600 (23 5/8)	660 (26)	1 350 (4′ 5 3/16″)	80.4 (79.13)	97.6 (96.06)	63.4 (62.40)	6.69 (2.007)	1 760	27.9
	0-10-0	$T_{16}{}^1$	1914, Schwartzkopf.	40 (24.9)	12 (171)	2.30 (24.76)	Simple 2 × 610 (24)	660 (26)	1 350 (4′ 5 3/16″)	68.1 (67.02)	84.9 (83.56)	84.9 (83.56)	6.71 (2.013)	1 820	22.5
	2-10-2	T_{20}	1922. Borsig.	70 (43.5)	14 (199)	4.36 (46.29)	Simple 2 × 700 (27 1/2)	660 (26)	1 400 (4′ 7″)	103.7 (102.06)	127.4 (125.39)	95.3 (93.79)	8.45 (2.535)	2 310	28.9

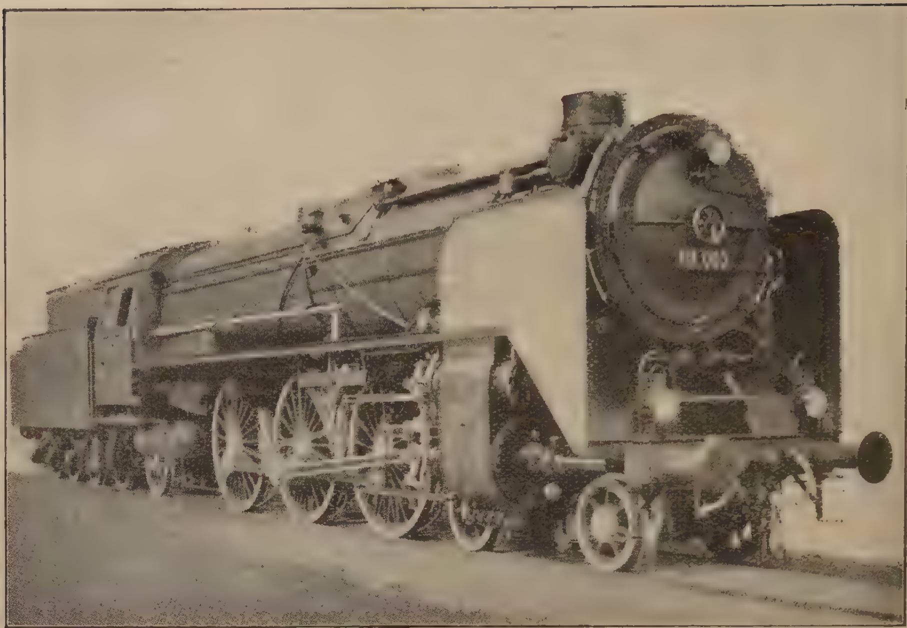


Fig. 24. — Four-cylinder standard *Pacific* locomotive of the State Railways.

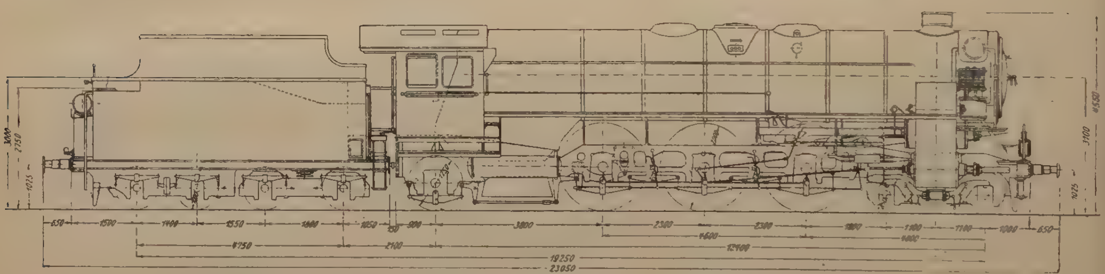


Fig. 25. — Four-cylinder standard *Pacific* locomotive of the State Railways.

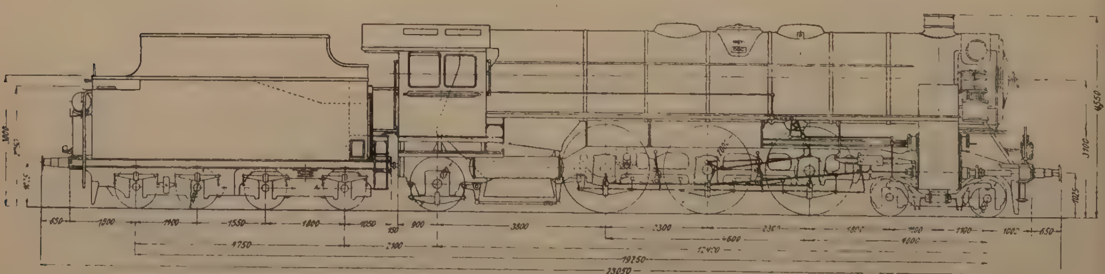


Fig. 26. — Two-cylinder standard *Pacific* locomotive of the State Railways.

tween different types of locomotives in the repair shops.

* * *

In order to be able to undertake this immense task, a new organisation had to be created in order to investigate the practicability of the proposed standardisation.

A special office was opened at Messrs. Borzig's Works at Tegel near Berlin and started its work under the title : *Office for the Standardisation of locomotives for the German State Railways.*

All the principal locomotive builders took part in the organisation by lending specialist engineers, and staff qualified to contribute to the work, thereby enabling it to profit by the experience acquired by the builders in question.

Based on the detail parts previously standardised by the « Alna » and the « Elna » (*Lokomotiv-Normen-Blaetter*) the Standardisation Office proceeded to design new classes of locomotives in conjunction with the Drawing Office of the Central Railway Office of the German Railways (E. Z. A. = *Eisenbahn-Zentral-Amt*) and the Locomotive section of the Central Administration of the State Railways.

The preliminary investigations by the manufacturers having been completed, in agrement with the State Railways, a number of new standard classes was produced. The Standardisation Office prepared the general arrangement diagrams to a scale of 1 : 40; these diagrams after consideration by the Locomotive Section were approved by the General Management of the State Railways.

In this way designs were prepared, and it is proposed to build the following classes of *superheated locomotives* for use on *main lines :*

1. 4-6-2 type locomotive for express trains divided into two classes :

— *4-cylinder compound* (figs. 24 and 25),
— *2-cylinder simple* (fig. 26),

in order to ascertain the *most economical method of using superheated steam* under service conditions;

2. 2-8-2 type three-cylinder locomotive (fig. 27) for stopping passenger trains;

3. 4-6-0 type two-cylinder locomotive (fig. 28) for stopping passenger trains;

4. 2-10-0 type locomotive for goods trains divided into two classes :

2-cylinder simple;
3-cylinder simple (figs. 29 and 30);

in order to compare in service *these two methods of using the steam;*

5. 2-8-0 type, two-cylinder locomotive (fig. 31) for goods trains;

6. 2-6-0 type, two-cylinder locomotive (fig. 32) for goods trains;

7. 4-6-4 type, two-cylinder tank locomotive (fig. 33) for stopping passenger trains;

8. 2-6-2 type, two-cylinder tank locomotive (fig. 34) for stopping passenger trains;

9. 2-10-2 type, tank locomotive for goods trains divided as the 2-10-0 mentioned above into two classes :

— *two-cylinder* simple,
— *three-cylinder* simple (fig. 35),

in order also to be able to compare *these two methods of using the steam;*

10. 2-8-2 type, two-cylinder tank locomotive (fig. 36) for goods trains.

Fig. 29. — Three-cylinder standard *Decapod* goods locomotive of the State Railways.

The design of these main line locomotives is based on a *weight on rail* of 20 t. (19.7 English tons) per axle (figs. 40 and 41) fixed by the strength of the track and bridges.

The following types of *non-superheated* locomotives have been designed for *shunting* :

11. 0-10-0 type, tank locomotive (fig. 37) for *shunting* in yards with *solidly laid track;*

12. 0-8-0 type, tank locomotive (fig. 38) for *shunting* in yards with *less solidly laid track;*

13. 0-6-0 type, tank locomotive (fig.39) for *shunting* in yards with *lightly laid* track.

20 t. (19.7 English tons) has been fixed as the weight on rail for the 0-10-0, and 17.5 t. (17.2 English tons) for the 0-8-0 and 0-6-0 types.

For *station service* and *lines with small traffic*, locomotives with a loading of 15 t. (14.8 English tons) per axle are under investigation, the series being :

14. 2-6-0 type locomotive for passenger and goods trains;

15. 2-6-0 type tank locomotive for passenger trains;

16. 2-8-2 type tank locomotive for goods trains.

All the *main line* locomotives are provided with *feed-water heaters*.

Having designed sixteen different types of standard locomotives, the standardisation of their dimensions was taken in hand.

As *standard dimensions* of parts the following have been selected :

— outside diameter of *boiler* :
1 900 mm. (74 3/4 inches);

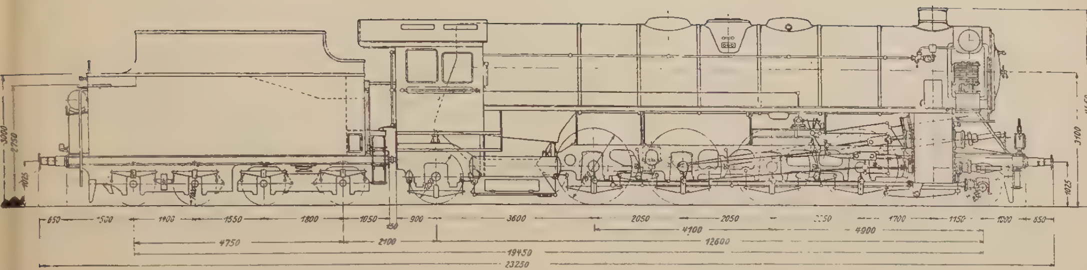


Fig. 27. — Three-cylinder standard *Mikado* passenger locomotive of the State Railways.

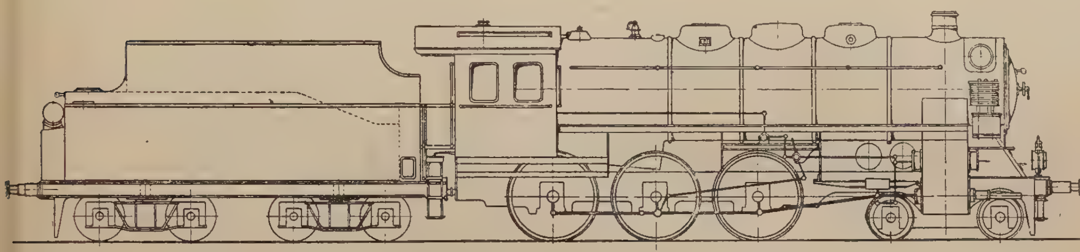


Fig. 28. — Standard *Ten wheel* passenger locomotive of the State Railways.

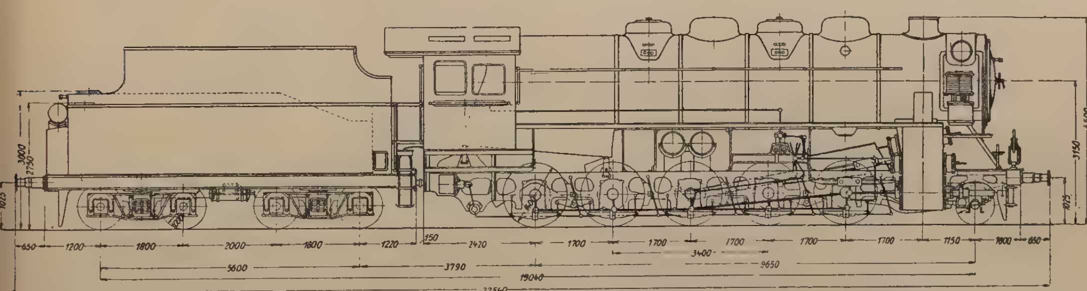


Fig. 30. — Three-cylinder standard *Decapod* goods locomotive of the State Railways.

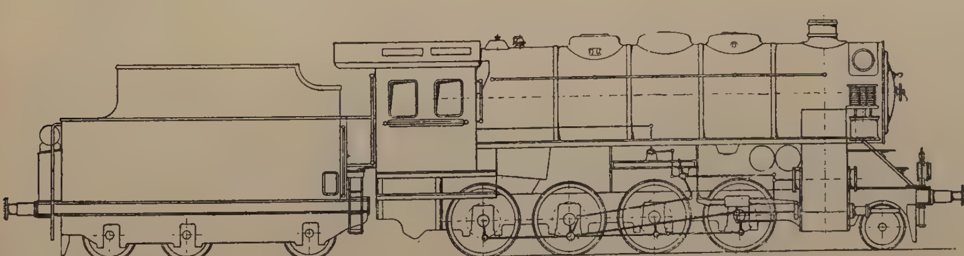


Fig. 31. — *Consolidation* standard goods locomotive of the State Railways.

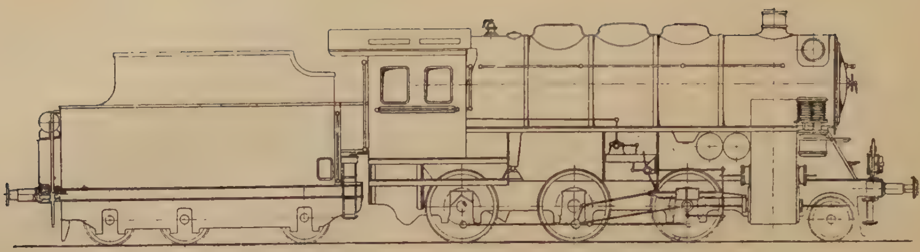


Fig. 32. — Six-coupled standard goods locomotive of the State Railways.

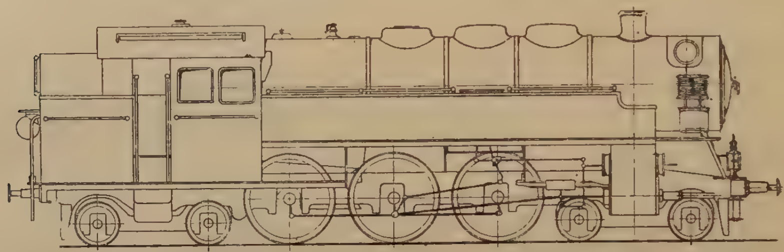


Fig. 33. — Standard *Baltic* passenger tank locomotive of the State Railways.

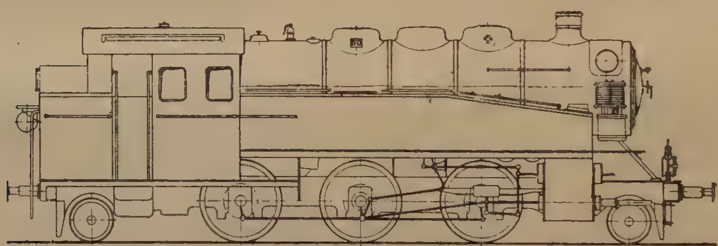


Fig. 34. — Standard *Prairie* passenger tank locomotive of the State Railways.

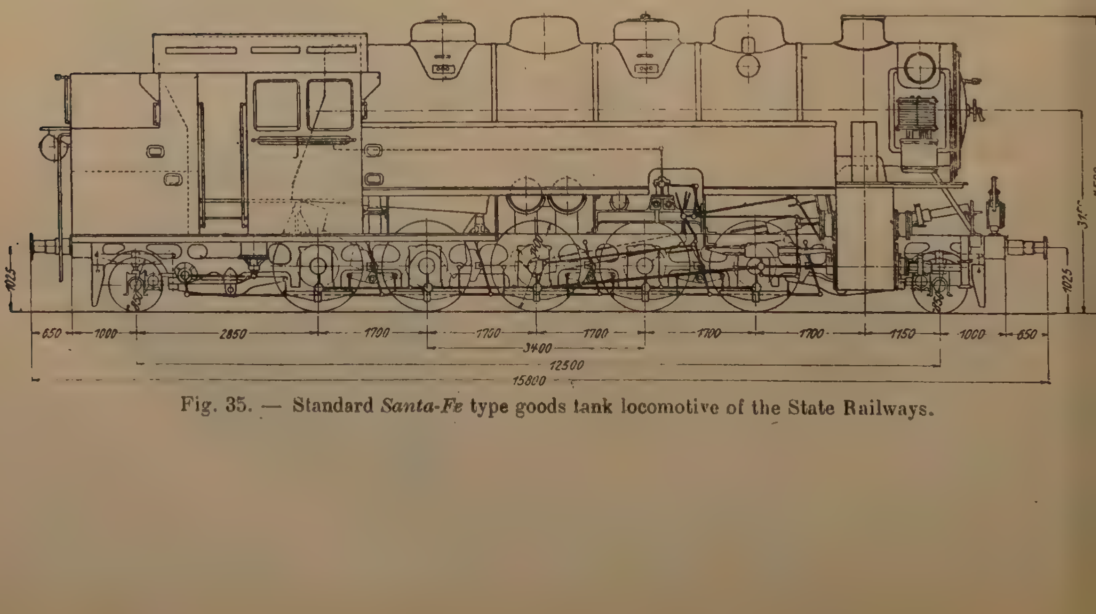


Fig. 35. — Standard *Santa-Fe* type goods tank locomotive of the State Railways.

1 800 mm. (70 7/8 inches);
1 700 mm. (66 15/16 inches);
1 500 mm. (59 inches).

— inside diameter of *cylinders* (except compound):

650 mm. (25 5/8 inches);
600 mm. (23 5/8 inches);
570 mm. (22 7/16 inches).

— *piston* stroke :

660 mm. (26 inches) for *main line* locomotives;
630 mm. (24 3/4 inches) for *shunting engines.*

— diameter of *driving wheels :*

2.000 m. (6 ft. 6 3/4 in.) for *express engines;*
1.750 m. (5 ft. 9 in.) for *stopping passenger train engines;*
1.400 m. (4 ft. 7 in.) for *goods engines;*
1.250 m. (4 ft. 1 3/16 in.) for *shunting engines.*

— diameter of *carrying wheels :*

0.850 m. (2 ft. 9 1/2 in.) for *bogie wheels;*
1.250 m. (4 ft. 1 3/16 in.) for *truck wheels.*

As regards the details of construction and equipment, all the locomotives using superheated steam will be fitted with superheaters consisting of four 30-38 mm. (1 3/16 and 1 1/2 inch) pipes in a 125-133 mm. (4 15/16 and 5 1/4-inch) tube; when the length of the tubes exceeds 5 m. (16 ft. 5 in.) the diameter of the large tubes will be 135-143 mm. (5 5/16 and 5 5/8 inches). *All the engines* are mounted on *bar frames.* Because of the length of the boiler on the main-line engines, a leading bogie, or Bissel, is used in all cases, including goods engines. The trailing bogies or bissels are the same as the leading ones on the tank engines for main line service. Experience shews that, even on goods engines, the carrying wheels help both the track and the driving wheels.

The leading bogies of the 4-6-2, 4-6-0 and 4-6-4 locomotives are the same, and so are the trailing bissels of the 4-6-2 and 2-8-2 locomotives. All the leading and trailing bissels of the goods engines, with or without tenders, are interchangeable.

In general it will be noticed that :

1. the Belpaire *firebox* has been given up;

2. bar-type *main frames* are adopted;

3. the *bissel* is adopted for all goods engines.

* * *

We have endeavoured to give a chronological table of the development of design of the locomotive stock of a great railway system at the present time endeavouring to lower the capital costs which, owing to the size of the system, are so great.

We have sketched on general lines the whole of the technical tendencies at present dominating the question and have analysed the *difficult problem* of the *standardisation* and *unification* of locomotives, a complex matter frequently hindered by the individualistic spirit.

What is required to-day on the principal railway companies is the reduction in the number of *classes* of locomotives in service and the *purchase* of these engines in *large numbers.*

This *unification* of the stock and the *interchangeability of repair parts* result in appreciably reducing the purchase price of the engines and lowering the cost of maintenance.

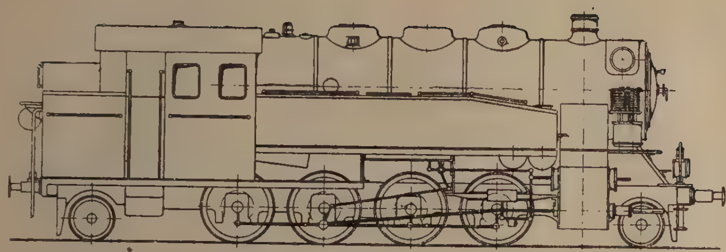


Fig. 36. — Standard *Mikado* goods tank locomotive of the State Railways.

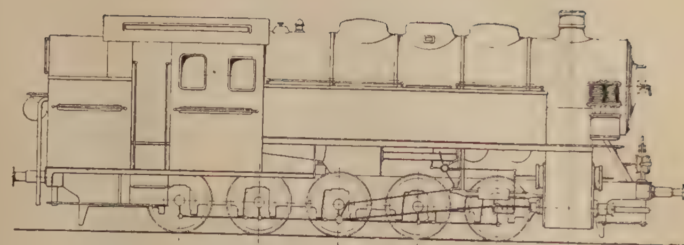


Fig. 37. — Standard ten-coupled shunting tank locomotive of the State Railways.

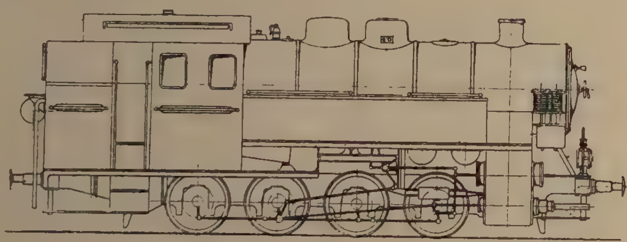


Fig. 38. — Standard eight-coupled shunting tank locomotive of the State Railways.

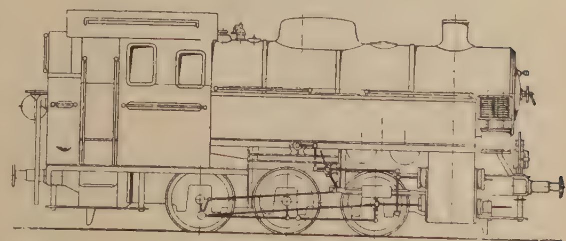


Fig. 39. — Standard six-coupled shunting tank locomotive of the State Railways.

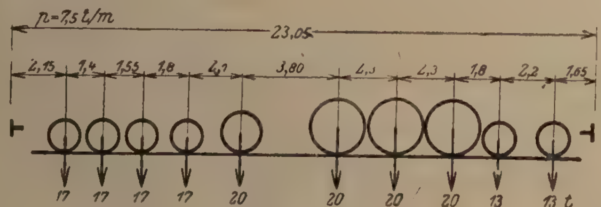


Fig. 40. — Distribution of weight per axle of the standard express *Pacific* locomotive and 32 m³ (7 040 gallons) bogie tender, of the State Railways.

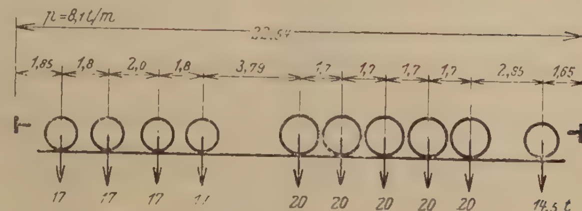


Fig. 41. — Distribution of weight per axle of the standard *Decapod* goods engine with its 32 m³ (7 040 gallons) bogie tender, of the State Railways.

In this way *savings* are made :

1. In drawing office costs at the builders' works as the details are settled once for all, and the number of drawings required is reduced to a minimum;

2. In the cost of placing the orders in the works and in starting the work, as the number of tools, gauges, etc., is lessened, and the manufacturing methods are settled once for all.

Finally, the *workshops* become specialised in the maintenance of a small number of types of engines; the stock of spares in the *stores* is reduced which leads to a simpler control and to fewer patterns.

The *time of repair* is also shortened as all parts can be kept ready in the stores.

As regards the *Operating Department*, this *homogeneity of the rolling stock* allotted to certain services results in enormous advantages at the *sheds* and *stations*.

It also satisfies the ideas of the present time in which *simplification* is considered to be the basis of *up to date organisation*.

[656. 256.3 (.492)]

Automatic block signalling organisation on the Netherland State Railways, (1)

By J. H. VERSTEGEN,
ENGINEER.

Figs. 1 to 18, pp. 119 to 141.

(From *De Ingenieur.*)

The first installation of the automatic block system in Holland was completed on the 8 June 1926 on the Gouda-Oudewater section, and was the result of a voyage of investigation in America made by the Chief Signalling Engineer of the Netherland Railways, Mr. A. van Driel van Wageningen, accompanied by the Engineers H. P. Maas Geesteranus and J. H. Verstegen.

***

The automatic block used on a wide scale for more than twenty-five years in the United States of North America has been developed there considerably and at the present time it is installed on more than 70 000 km. (43 500 miles), or more than a third of the railways in the United States using semaphore signals. In Europe the automatic block has only commenced to be used recently : in France, although the Midi tried it twenty-five years ago, it is only during recent years that it has been fitted on a large scale, as, for example, on the State Railways which have just placed orders with each of the three Companies specialising in the manufacture of this material, to equip 100 kilometers (62 miles) with the automatic block. In England its use is becoming more frequent; in Germany it has not yet been used on main lines. The chief reasons for Europe lagging behind America in this direction are probably the same in the different countries of Western Europe.

Owing to the very dense population and the system of level crossings with gate keepers, a level crossing was required at almost every block box which made it necessary to have staff right at the block box itself. In addition rates of wages are much lower in Europe than in America. The economies everyone has endeavoured to effect in all directions since the war have resulted in level crossings keepers being abolished at many places, so that introducing the automatic block would be to suppress the whole of the staff at such points.

***

The practical origin of the automatic block is to be found in the invention of the *track circuit* in 1870 by the American, William Robinson († 1921) the founder of the « Union Electric Signal Company ».

In order to form a track circuit, a portion of the line is insulated from the

(1) Paper read at the Meeting of the Electro-Technical Section of the Royal Institution of Engineers at Utrecht the 13 October 1926, and published in the Dutch review *De Ingenieur* of the 26 March 1927.

neighbouring parts by replacing the usual steel fish plates at the end of the insulated section by insulating fish plates. If now we connect to one side of the insulated section a source of current B and to the other a relay R (fig. 1) we shall have completed a track circuit. In addition to the useful current passing through the rails which should operate the relay, there is a certain loss of current passing through many secondary paths from one rail to the other, such as the wooden sleepers and the ground. The resistance to losses of current, known as the insulation resistance of the track, largely depends upon the state of the track and atmospheric conditions : one of the first conditions for proper working is therefore to have at all times sufficient current to operate the relay.

When a train occupies the insulated section, the wheels and axles form a short circuit which releases the relay. The operation of the track circuit therefore depends upon the difference of resistance of one rail in relation to the other in the insulated track, according as this is or is not occupied by a train. The relay is energised when no train is in the section and inversely.

As we have seen, preference has been given to the current being normally on the line and the relay energised when the track is unoccupied : so that if the apparatus gets out of order, an indication of the danger is given.

It should be added here incidentally that this arrangement has been used in Holland for very many years in different ways, and in conjunction with other apparatus for protecting trains in the stations. Of course, in this case the size of the installation is much smaller than in that of the automatic block.

If now we cause a current to flow through the contacts of the relay R (fig. 1) in the energised position (that is, for line unoccupied) which works a signal with motor, and by which the signal arm is moved to the off position and held there, we shall have arranged for the signal to give line clear when the line is unoccupied and stop when the line is occupied, because in this latter case the current holding the arm in the off position is cut off and the arm falls by its own weight to the stop position. If we wish to apply the above to the automatic block, it is necessary to divide the whole of the section of the line into insulated lengths (blocks) and to place at the beginning of each block a signal giving automatically the situation in the block concerned. It is clear that the length of the insulated lines will become very great, and that furthermore, the insulation resistances of the lines become relatively small, which may have considerable effect on the working of the relays.

For this reason, if we wish to reduce the number of failures to a minimum, the installation and upkeep of the insulated tracks must be carried out with the greatest care, the relays must be very accurately made and sensitive, and the arrangement for operating the signal arms be of very special construction.

* * *

The block system briefly described above is called *open line block*, that is to say, that the signals automatically give line clear in the case of a section unoccupied by a train, and are, in consequence, normally off.

Use is also made of the system of *automatic block with line closed*, in which the setting of the signal to clear depends not only on there being no train in the section protected, but also on the presence of a train in the preceding section.

In this system, the train itself puts the signal it has to pass to clear and restores it to danger after passing it.

If the train movement is not extraordinarily dense the automatic block with line closed has some advantages as, for example, saving of current, as the arms have not to be held normally at clear.

The greatest advantage, however, consists in the fact that as a signal does not remain ordinarily any length of time in the off position, the danger of an arm sticking in the off position as a result of frost is removed (a danger which exists with the line clear automatic block). It is for this reason that at first in America, the line closed system was largely used, and in France it was used exclusively. However, the electrical connections in the line closed system are very complicated : this led the Americans to endeavour to reduce the disadvantages of the line clear block system to the minimum, and to use at present this system almost entirely as thereby they have been able to simplify the connections. In this way, a modern American continuous current signal movement, like those used on the Gouda-Oudewater line) only takes $\pm$ 10 milliamperes at 8 to 10 volts to keep the arm of the automatic signal at the clear position, a very low consumption.

In addition, the American specialists consider that the perfected construction of the operating gear, assembled as a unit with the arm and bolted to the signal post, definitely avoids the danger of the arm remaining in the off position, when the current holding it off has been cut off.

They even go further in that they do not provide in their connections for the line clear automatic block, any safety device for ensuring that a signal which has protected a train before the preceding signal can be put at clear, a thing always done in Europe. Thus, for example, on the Berlin elevated and underground railway, when the line clear automatic block was installed, this control was always applied.

Certain American Railway Companies have not complete confidence in the signal falling to danger, and for this reason introduce the above control, just as they fit the arm operating gear at the foot of the signal post with rodding carried up to the arm, as they consider the upkeep of the operating motor placed high up is more or less difficult to carry out.

This drawback is, however, very slight when compared with the great advantage of having the gear placed high up beside the arm, with only a very short length of shafting exposed to the atmosphere. In addition, a ladder, with platform and hand-rail built against the signal post, makes it easy to get to the gear, and carry out any repairs.

In France, preference is now beginning to be shewn for simplified connections and consequently to the use of the open line automatic block, experience having shewn that most interruptions in working are attributable to the complicated connections.

It should also be noted that there are automatic block systems which depend, not on track circuits, but upon rail contacts operated by the wheels. Such installations are, however, not so safe as those with track circuits because they do not give a continuous control of a section of the line whether occupied or not by a train.

* * *

As we have just seen above, an open line automatic block consists essentially of an insulated section of line with, at one end, a relay whose contacts allow the passage of the current working the driving gear of the signal protecting the section, whilst at the other end is to be found the source of current which works the relay through the rails (fig. 2).

From now on we will use the conventional signs of figure 2 to represent a closed or open electric circuit. The points *a*, *b* and *c* agree in both cases in indicating the contacts. The direction of circulation of the current cut by the small arc of circle having its top at *a* is interrupted. Thus the two first small figures of figure 2 represent the current

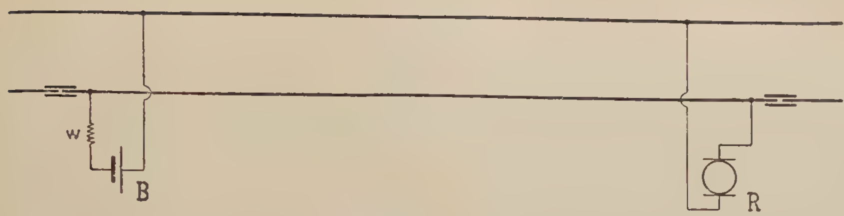


Fig. 1. — Principle of the track circuit.

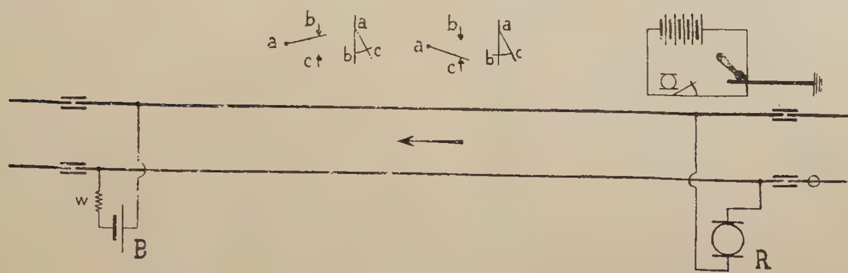


Fig. 2. — Diagram of the connections of an automatic block with continuous current.
Length of the block = length of the line insulated.

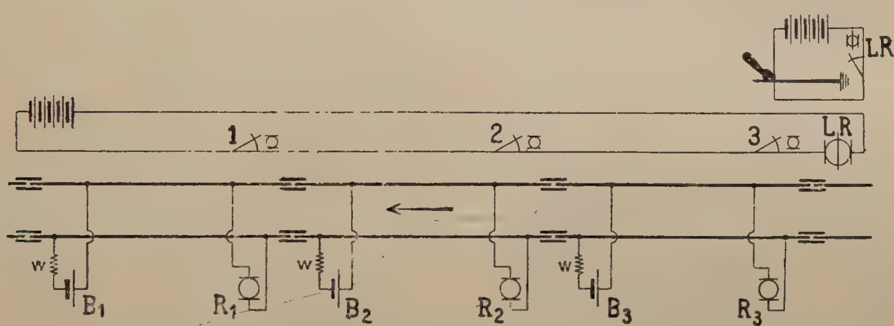


Fig. 3. — Diagram of the connections of a line clear automatic block *with* continuous current track relays.
Length of the block = three lengths of insulated lines.

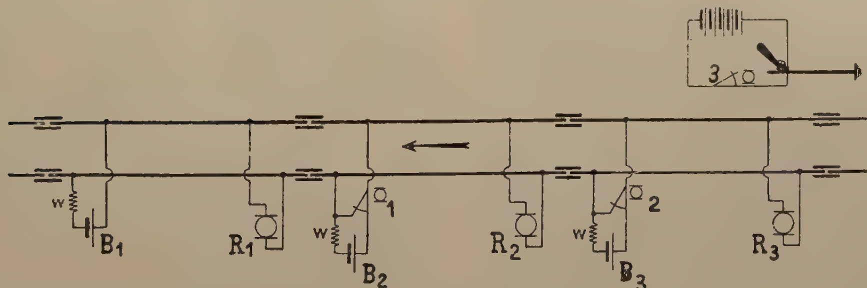


Fig. 4. — Diagram of the connections of a line clear automatic block *without* continuous current track relays.
Length of the block = three lengths of insulated lines.

flowing by *ab*, the other two small figures shewing the current passing by *ac*. This method of representing a closed or open electric circuit greatly adds to the simplicity and makes the electric diagrams much more easily read.

(To increase the insulation resistance of the line, and to be more independent of stray currents, two lines of rails are insulated from the adjacent parts of the track by insulated fish plates.)

In the diagram shewn in figure 2 we have taken the length of the insulated section of line to be equal to that of the block. Although frequently the insulated length of line is as much as 1.5 km. (1 650 yards), it most often happens that the length of the block is superior to that of the insulated section.

It is then necessary to subdivide the block into two or more sections, each insulated one from the other. The consequence is that setting the signal to danger ought to be rendered dependent upon the energising of two or more relays spaced along the section of line under consideration. This is the actual case for Gouda-Oudewater where the blocks are about 3 km. (3 300 yards) long, although at first as a trial 1 000 m. (1 100 yards) were taken as the maximum length of the insulated section.

The dependence of the position of the signal of different relays belonging to one block has been realised by maintaining through their respective contacts an energising current actuating a special relay known as a *line relay* placed near the semaphore. The signal arm operating gear then depends upon the line relay L. R. (fig. 3). To complete the circuit, including the line relay, electric conductors laid the full length of the section of the line have to be used : insulated electric wire was used for this purpose to avoid any danger of the wires for the two directions coming into contact. It should be added that these reliable, though costly, connections have only been used as a trial. On the Berkum-Dedemsvaart section less expensive connections (fig. 4) have been used however, the cutting off of the current from a track circuit depending upon the track relay of the following part of the same block, which means in the end that the relay near the signal has to indicate the position in the whole block. In this arrangement no wires run along the track, nor is there any line relay and this means a great saving. (Let us add that we must be careful when switching off the supply of current W. to provide across the contacts of the relays a short circuit by the track to prevent a relay being energised by a leaking current for example.)

* * *

Before explaining why in the first test the arrangement using line relays was preferred, it is as well to give some explanation about the kind and strength of the currents used, as well as of the electrical resistances encountered.

For the Gouda-Oudewater section it was first of all considered that alternating current should be used both for the track circuit and to work the signals.

The use of alternating current for the automatic block dates from the electrification of railways when the rails had to be used as conductors for two kinds of current. When continuous current traction is used, the kind of alternating current utilised for the track circuiting does not matter. On the other hand, when alternating current is used for traction purposes, an alternating current at higher frequency can be used for operating alternating current relays. These relays, acting much like a steam locomotive regulator, give for a clearly defined frequency alone, sufficient movement to close the contacts.

With alternating current the layout of the connections becomes complicated. When the two rails of a track are used as the return circuit it becomes neces-

sary to provide a path for this return current through the insulated joints of the rails. This path, however, cannot let the track circuit alternating current pass, and this is assured by suitable groups of chokes.

Alternating current for the automatic block having advantages over continuous current, has also been applied to steam lines. One of these advantages is that alternating current track circuits are less affected by earth currents. In installations using alternating current, signals with arms worked by alternating current motors can be used. Daylight signals are of course also used giving the same indication by day as by night. These signals have no arms. The daylight signals have come into use more generally since the special electric lamps required by this system have been made available.

These lamps work with low tension current (12 volts for example) and have a very powerful point of light placed at the focal centre of a lens. By using a special lamp complete with its lens for each colour the signal has to shew, it is possible to place all the moving parts required to change the signal indications clear of the lamp unit (as for example the relays).

In addition, as we have already said, alternating current shews a very great advantage from the point of view of the track circuit. The insulation resistance of the track can become very low in certain unfavourable conditions: for example, during long continued rains, melting snow, poor ballast, defective drainage of the track, etc., which may result in the track relay not being energised even when the line is unoccupied. (The signal would of course in this event go to danger). With the alternating current track circuit, however, two-phase relays can be used, such as the bi-phase motor relays, in which one of the phases is constantly fed by the line current (that is, a current independent of the state of the track) whilst the other is inserted in the track circuit which is fed by the traction current reduced to a tension of 1 or 2 or up to 20 volts by static transformers.

By making the first phase do the greater part of the work, so that the second only takes a small amount of current, this type of relay can be made very sensitive, and is able to operate under more unfavourable conditions than the continuous current relay which depends upon the track entirely. Consequently with alternating current, the length of an insulated section can be increased, diminishing the number of relays and accessories required.

Alternating current was not used, however, in the Gouda-Oudewater section because of the high cost of providing the electric current, and also because the Post Office Authorities refused to sanction the laying of insulated electric conductors under a tension of 220/380 volts alongside the telegraph lines. In America, however, the Telegraph Companies allow conductors carrying up to 550 volts to be so laid. The possibility of using daylight signals with portable batteries of accumulators, and of lighting the signal by the train itself by means of special relays, was also considered. The complication of the connections increasing the risk of derangement prevented this being done, especially as in addition all the advantage of alternating circuit relays would have been lost. For this reason the use of continuous current with ordinary cells for the track line and signal arm movement circuits was preferred. (The alternating current system will, it is expected, be used with daylight signals, bi-phase motor relays, track transformers and groups of impedances on the section between La Haye and Voorschoten, when the Rotterdam-Amsterdam line is electrified) (fig. 5).

* * *

In the Gouda-Oudewater section caustic

soda cells are used as the source of current, made up of a solution of Na OH in water with the positive pole in protoxyde of copper and the negative pole in zinc. These cells are largely used in America as a result of the shortage of copper sulphate, since the war.

The chemical reactions are :

$2\,NaOH = Na_2 + (OH)_2$;
$Na_2 + H_2O = 2\,NaOH + H_2$;
$H_2 + CuO = Cu + H_2O$;
$(OH)_2 + Zn = Zn(OH)_2$;
$Zn(OH)_2 + 2\,NaOH = Na_2ZnO_2 + 2\,H_2O$.

The cylindrical poles (protoxyde of copper inside the zinc) are suspended from the porcelain cover of the jar containing the Na OH solution, so that renewal is easy. One of the great advantages of this cell, when used in the automatic block, is its small internal resistance : 0.045 ohm.

To move a signal to the off position 2.5 amperes at 8 to 10 volts is taken, whilst holding the signal off only requires $\pm$ 10 milliamperes at the same tension. When using these cells, one series per signal is sufficient as they can give as much as 20 amperes.

The capacity is 500 ampere-hours and in commerce cells of as much as 1 000 ampere-hours can be found. The tension at first is $\pm$ 0.7 volt and at the end $\pm$ 0.6 volt. The condition of the cell can be seen from the outside by the state of corrosion of the zinc which, after about three quarters of the capacity has been used, is attacked from the bottom upwards, in which direction the thickness of the zinc also increases.

For the signal and the line currents sixteen cells are coupled up in series and placed in a concrete pit to protect them from frost, as the voltage falls in winter.

For each track circuit two cells are coupled in parallel to increase their useful life; they are placed one above the other in a wood crate which is lowered into a metal tube buried in the ground. A small box holding the track relays with the different connections is carried by a support bolted to the top of the tube. Beside the crate with the relays other small boxes are provided in which are fitted the connections from the conductors carried on the telegraph posts. The lightning conductors and the passages for the connections to the outside cables are also included therein.

The current from the track batteries (for the track circuit therefore) is regulated by a small variable resistance (0.2-1.2 ohms) so that the current has a minimum intensity when a train occupies the track.

For the different parts of the insulated lines ($\pm$ 900 m. [$\pm$ 984 yards]) of the Gouda-Oudewater section, the tension at the rails on the battery side varies from 0.5 to 0.56 volt with a track current intensity of 185 to 220 milliamperes. On the relay side the tension is 0.46 to 0.52 volt with 97 to 103 milliamperes. The above figures were taken in wet weather. The whole of the circuits were provisionally set so that the track relays received about 100 milliamperes : the current intensity to give the maximum attraction at the contacts of the relays being 90 milliamperes. The intensity at the battery reached 500 milliamperes with the line occupied. One other advantage of the short circuit, from the point of view of safety, is that the tension at the rails near the battery falls considerably, to 0.25 volt for example, because in this case much of the voltage is lost in the regulating resistance. If then, for one reason or another the short circuiting by the train is not as good as it might be, the risks of the relay not acting are reduced by the small tension remaining.

It also happens that the train running into the insulated section from the relay end, the short circuiting occurs close to the relay which can then be relied upon to release the contacts. To restore the relay to its primitive energised position,

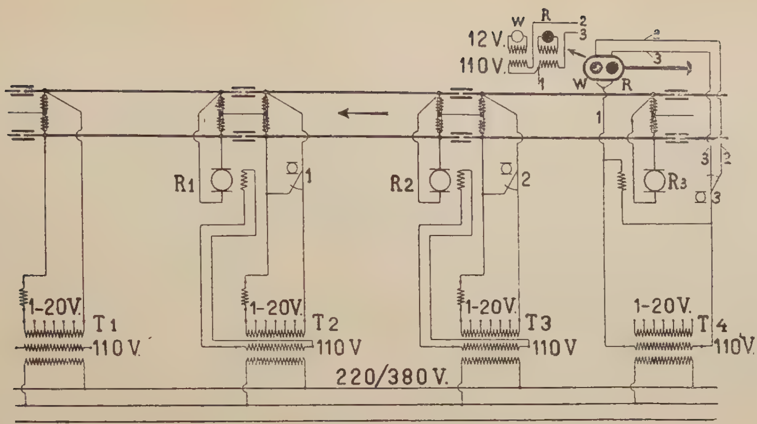


Fig. 5. — Diagram of the connections of an open line automatic block *without* line relays using alternating current and daylight signals.

(W = white light : clear. — R = red light : stop.)

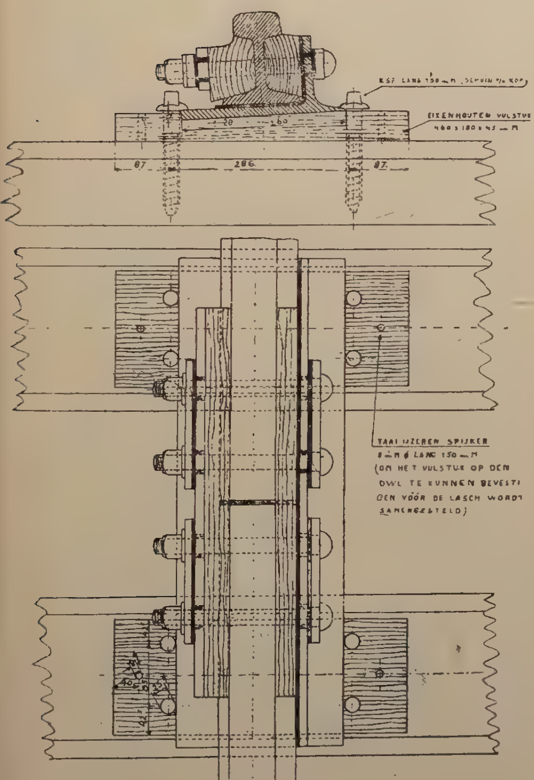


Fig. 6. — Insulated rail joint, type Weber N. P. 46.

Scale : 1 : 12.

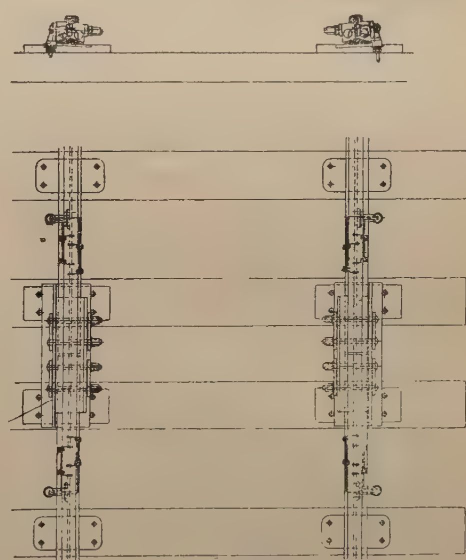


Fig. 7. — Attaching the electric wires to the rails by means of special bends.

Explanation of Dutch terms : Eikenhouten vulstuk 460 × 180 × 45 mM. = Oak packing piece 460 × 180 × 45 mm. (18 1/8 × 7 1/8 × 1 3/4 inches). — Taaiijzeren spijker 8 mM ∅ lang 150 mM (om het vulstuk op den dwl. te kunnen bevestigen vóór de lasch wordt samengesteld) = Iron spike 8 mm. (5/16 inch) diameter and 150 mm. (5 5/16 inches) long (to fasten the packing piece to the wood sleeper before making the joint).

a current of an intensity double that required to hold the relay in the energised position is required.

If the locomotive should run into the insulated section from the battery end, the short circuiting occurs at about 900 m. (984 yards) from the relay, which might result in the relay remaining in the energised position when there was a train in the block. This could occur, for example, as a result of a leak of current owing to badly insulated joints in the adjacent sections of the line. However quite independently of this reason, in the diagram of figure 2 in which the length of the insulated section is equal to that of the block, and in that of figure 4 where no line current is used the relay *has* to be placed at the end the trains enter the block because the signal is placed at this point.

To calculate from the above figures, the insulation resistance of the line, we can use the approximate formula

$$\frac{E + e}{2\,(I - i)} = \text{resistance of the track,}$$

in which

E = tension at the rails on the battery side,

e = that on the relay side,

I = intensity of the battery current,

i = that of the relay current,

all these quantities being taken for line unoccupied.

$\frac{E + e}{2}$ is then the average tension at the rails supposed to cause the leaking current $I - i$.

From this equation when several lines, of about 900 m. (984 yards) length are in service, we get an insulation resistance of 4 to 6 ohms. Although these numbers were recorded in wet weather, the test ought to be repeated in winter to enable definite conclusions to be drawn.

To obtain values such as the above for tension and current intensity, much care must be given to the insulation and the good conductibility of the line.

First of all, there are the insulated joints.

Up to recently the Netherland Railways used as insulated fish plates, fish plates in wood with a piece of fibre between the ends of the rails. These fish plates give sufficient insulation, but mechanically are not strong enough, and have to be replaced frequently. For this reason they are now being replaced by the Weber joint (fig. 6) in which the wood fish plate is reinforced by a strong rolled steel section insulated from the rails by sheet fibre, and by fibre bushes round the bolts. This joint is also used on the Gouda-Oudewater section and has given excellent results.

Secondly, the rails must not come into contact with the ballast. Furthermore, the ballast must be well drained. (When the figures mentioned above were obtained, the track had not been made good in regard to the above points, so that it is to be expected that better figures will be realised).

For each of the connections of the relays and batteries to the rails, a vulcanised armoured cable with double wire (for safety) has been used. As the two wires are each separately attached to the rails there is appreciably greater safety.

Several methods of attaching the cables to the rails have been tested. In the first method, the movement of the rails occurring during the passage of a train is taken up by the sheathing of the cable by fitting the cable and its sheathing with enough slack in a connecting bend fastened to the rail. From this bend two insulated bonds lead to copper wires fastened to the rail (fig. 7). Each copper wire is fastened to the rail at two points.

In the second method, the rail movement is taken by connections going to the rails, this being done giving them a suitable shape, whilst the cables are fitted with their connections in a small special wooden box (fig. 8). In this latter method, two different ways have been used to secure the copper wires to the rails, one by conical wedges with grooves for the copper wire, and the other by bolt and nut.

As regards the good conductibility of the rails themselves, it is not to be expected that the ordinary fish plates in steel can be retained. These fish plates offer far too great resistance to the low tension currents used. In consequence two copper wires have been provided at the joints connecting one rail to the other (fig. 9).

So as to protect these bonds, the copper wires have been placed between the rail and the fish plates, and have been secured to the rails by means of conical wedges with grooves in which the ends of the wires are lodged.

On the Gouda-Oudewater line about 5 000 of these bonds had to be made, and 10 000 holes had to be drilled in the rails. This was done by means of special hand drills with which two copper bonds could be fitted to a joint in a few minutes. The work was done by contract and was completed in a month.

From the figures given above, the resistance of the rails with joints using ordinary fish plates and fitted with copper bonds to the passage of the current is very small.

This resistance can be calculated by means of the approximate formula $\frac{2\,(E - e)}{I + i}$, that is to say, from the difference between the tension at the beginning and at the end of the insulated section, divided by the average current intensity. The total resistance of two lines of rail each about 900 m. (984 yards) long, varies from 0.08 to 0.25 ohm.

The following table gives the characteristics of different lengths of track, as completed at the present time.

Tension of the line battery, in volts.	Current intensitty of the line battery, in milliamperes.	Tension of the track relays, in volts.	Current intensity of the track relays, in milliamperes.	Length of the track insulated, in metres (in yards).	Insulation resistance of the track, in ohms.	Resistances of the rails with copper bonds, in ohms.
0.5-0.52	106-110	0.49-0.5	100-105	100 (109)	70-100	0.09-0.3
0.51 0.56	123-133	0.51-0.55	101-104	300 (328)	17-25	0.09
0.47 0.54	146-190	0.45-0.52	97-103	± 700 (± 765)	6-10	0.08-0 3
0.46 0.56	155-200	0.44-0.54	97-115	± 750 (± 820)	5 1/2-8 1/2	0 08-0.3
0.45-0.54	155-200	0.43-0.52	95-105	± 800 (± 875)	5-8	0.08-0.36
0.5-0.56	185-220	0.46-0 52	97-103	± 900 (± 984)	4-6	0.08-0.25

A provisional graphical representation of these figures is given in figure 10; curve A is the average insulation resistance of the insulated sections which falls away quickly at first but after 300 m. (328 yards) becomes much flatter. Curve B represents the current intensity given by the track batteries and is a straight line up to 700 to 800 m. (766 to 875 yards). The curve C has been calculated from curve A by taking a current intensity of 100 milliamperes for all the relays and starting from the average rail resistance of the insulated section. The

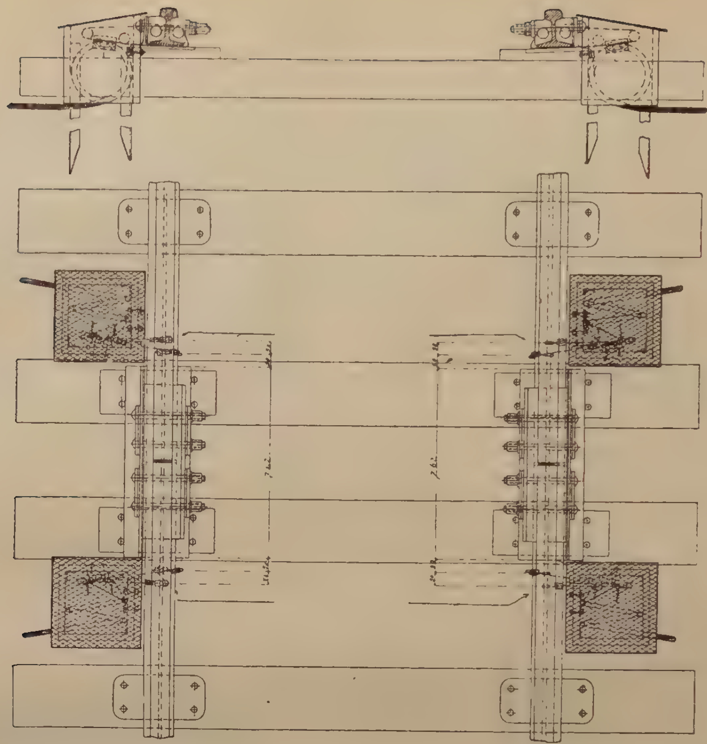
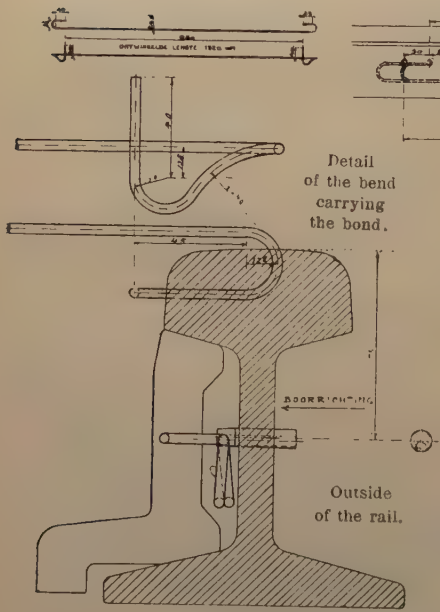
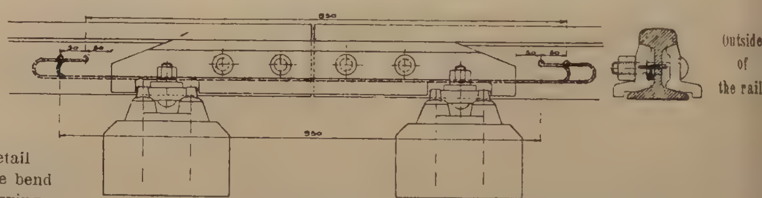


Fig. 8. — Connection of electric wires to the rails. Arrangement using small wooden boxes.





The 9/32-inch holes are to be drilled in the rail starting from the outside. A special rail drill is used with oil as cutting fluid. The drilling is continued until the drill projects 20 mm. (13/16 inches) through the hole. Drilling is not to be done in wet weather. The copper wire bond is to be put in place the same day the hole is drilled. The conical tinned plugs should be driven into the hole with the groove for the wire underneath. The wire and the plug should stand out the same amount. The plug should be driven by hand hammer in the direction the hole was drilled. Each bond consists of two copper wires (B & S No. 6) except at level crossings and in stations between platforms, where there are four, two on each side of the rail. The holes are arranged as shewn in the figure.

Fig. 9. — Details of the copper wire bonds at the ordinary fish plates.

Explanation of Dutch terms : Boorrichting = Direction of drilling. — Ontwikkelde lengte = Developed length.

resistance of the chain of relays has been taken as equal to 4 1/2 ohms.

Generally speaking, the above figures increase or decrease in a logical manner. As we have already said, the definite figures will not be available until later.

With line occupied the current intensities of the batteries vary from ± 450 to ± 700 milliamperes, usually reaching a value of ± 0.5 ampere.

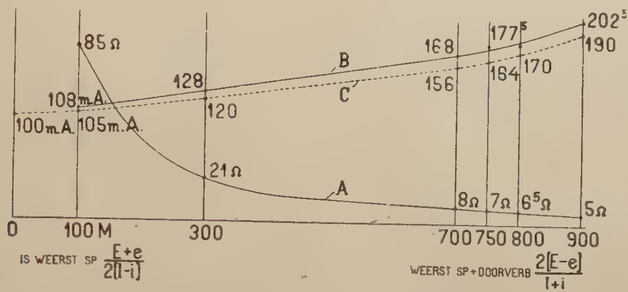


Fig. 10. — Graphical representation of the mean insulation resistance and of the current intensity to be supplied for different lengths of insulated track.

Explanation of Dutch terms :

Is. weerst. sp. = Insulation resistance of the track. — Weerst. sp. + doorverb. = Resistance of the rails + bonds.

NOTES :
- A = Average resistance of the insulated lines, in ohms, deduced from electrical measurements.
- B = Mean current intensity supplied by the batteries, in milliamperes, from electrical measurements.
- C = Theoretical current intensity, in milliamperes, supplied by the batteries, deduced from the curve A, supposing the track relays receive 100 milliamperes.

The figures of the rail plus the copper bonds resistances have no absolute value as they depend entirely on the accuracy with which the measurements have been made, seeing that the difference between the measured tensions have been brought into account. Many readings of tensions for lengths of 100 m. and 300 m. (109 and 328 yards) of line give the same figure. These measurements are close enough for the purpose for which they were taken, as they indicate that we are dealing with very low resistances. As soon as the copper bonds get out of order, very different results are found. By calculation, the resistance is found to be 0.15 ohm for a length of track of 1 000 m. (1 094 yards) (that is to say, 2 000 m. [2 188 yards] of rails plus the copper bonds).

The results of measurements for the calculation of the insulation resistance of the different tracks inspire much more confidence, as here we take into account the mean tension and the difference in current intensity, which is generally high, especially for the long lengths of track which are far from the most important and most used.

Care must also be taken so as to make sure that the resistance of the leads from the battery and relays to the track is low. This is one of the main advantages obtained by placing the batteries and relays close to the connections to the rails as compared with usual method with the ordinary block system of collecting the batteries and relays in a central place, such as a block cabin.

The calculations given in the appendix shew the same result.

* * *

The track relays are continuous current

relays with double windings in series, the two windings having a resistance of 4 ohms. This type of relay is much used in America. A commercial relay of 2 ohms, but using more current, can also be obtained. It is used principally for very long lengths of track and when the insulation of the track is very low. The results obtained so far with the 4-ohm relays have been very satisfactory.

The contacts are enclosed in a small glazed box with all the terminals placed outside on the porcelain cover.

In the energised position of the relays, the lower contacts, of silver, come in contact with the upper contacts, of gas carbon, the direction of the current through the contacts being silver-carbon in order to keep the contacts clean, and to have a constant and minimum electrical resistance.

This resistance may amount to 0.18 ohm but cannot exceed 0.3 ohm in service, whilst the current intensities for a 4-ohm relay with four contacts reaches for the holding off current values of $\pm$ 30 milliamperes, and for the energising current $\pm$ 60 milliamperes, and the holding on current $\pm$ 90 milliamperes. For this latter current intensity the contacts are pressed together with the maximum pressure, 48 gr. (1.69 ounces) per contact. The relay is built so that it can be placed either in a case or attached to any post, etc.

* * *

Let us now return to the comparison of the connections of figures 3 and 4, and explain why we preferred to equip the Gouda-Oudewater line in accordance with figure 3 rather than with figure 4, although in the latter case no line current was required. This is solely due to the fact that even small resistances have considerable influence in the circuits when the current intensities and tensions are low.

The resistance of the contacts can play an important part, so much so that usually two relay contacts are put in parallel to give increased safety.

Now in the diagram of figure 4 contrarily to what happens in figure 3, the track batteries supply current through the contacts of the track relays : in consequence, in figure 4, relay 2 will receive rather less current than relay 1 because the resistance of the contacts of the relays 1 is inserted in the circuit of the battery 2. If then, for example, through the track being wet, relay 2 no longer receives the same current intensity when the contacts are drawn together, the intensity in the relay 3 will in consequence be still smaller, etc. Let us add to this the possibility of the contacts of the relays themselves getting out of order, and we shall have given the reason why it was thought better to make a first test on the lines of figure 3. None the less it is expected a test will be made on the Berkum-Dedemsvaart line with the system shewn by figure 4 owing to its economy. Rather shorter lengths of insulated track will be used, and this will diminish the risks of failure. If the test does not give satisfactory results, it will always be possible to return to the system shewn in figure 3.

* * *

With regard to the semaphore, we have already said that the operating gear of the signal arm (that is to say, the motor and transmission with accessories and the electro-magnet holding the signal in the clear position) was connected to the arm, and that the whole was bolted to the post. This construction has enormous advantages when permanent way work is being done : the whole signal with its accessories can be fastened to any wooden or steel post.

Figure 11 illustrates an automatic signal in the clear position (the box for the relays is open).

Figure 12 shews the signal at stop.

The old house for the signalmen and for the crossing keeper will be noticed.

The motor is a continuous current series motor, 8 to 10 volts, consuming 2.5 amperes to set the signal to clear. The time required to move the signal to clear is three to four seconds. At the end of the movement of the arm this latter closes a contact in the holding on electro-magnet circuit. This magnet has windings of low resistance (26 ohms) and of high resistance (1 000 ohms). When the electro-magnet is energised, the low resistance windings and the motor are coupled in parallel, whilst the high resistance winding is short circuited. The motor and the electro-magnet then consume together 2.8 amperes. A ratchet device below the electro-magnet prevents the return movement of the shaft of the motor. Just after the holding-on electro-magnet is energised, the motor and the low resistance winding of the electro-magnet (in parallel) are put in series with the high resistance winding, and this reduces the current holding the signal at clear to $\pm$ 10 milliamperes.

When set to stop by cutting off the current, the arm falls by its own weight, and takes with it the motor with the operating gear in place. At the end of the movement it closes a contact (held during the outwards movement by a ratchet device) which allows a current to flow through the motor and a resistance which causes the motor to run as a dynamo and act as a brake.

All the operating gear is contained in a box hermetically closed by a door on the front. When this door is opened, all the moveable contacts mentioned above are exposed. A smaller door gives access to the motor with the gear holding the signal at clear; a side door gives access to the transmission gear.

The signal post is a Mannesmann tube on a concrete foundation : the wires are taken inside the post and at the top leave through a flexible metallic tube and go to the operating gear.

This operating gear, of American construction (being like the relays obtained from the General Railway Signal Company of Rochester, N. Y.), is used in different places with different kinds of current (of course using the special motor required by each). It can be used with 8 to 110 volts continuous current or with alternating current of 55 to 110 volts (25 to 60 periods) for the automatic, semi-automatic, or non-automatic block, with the signal arm to the left or to the right of the signal post, or in the upper or lower quadrant.

The light for the signal at night is assured by a paraffin lamp known as « longtime burning lamp » which burns day and night for 120 hours, without attention just as well with ordinary paraffin as with the special « longtime burning oil ». We are in negotiation for lamps with larger reservoirs because it would be very desirable if the lamps only required to be cleaned and filled once a week.

* * *

In accordance with the practice of the Netherland Railways the caution signal has been placed 500 m. (547 yards) before the block signal.

This caution signal gives two indications : 1. Pass at reduced speed (arm at 45° downwards, green light at night); 2. Pass, line clear (arm at 45° upwards, white light at night). These indications correspond respectively with the stop position of the block signal (horizontal arm, red light at night) and with the pass position of the block signal (arm 45° upwards, white light at night) respectively.

Figures 13 and 14 indicate the two positions of the caution signal.

* * *

To ensure the dependence of the caution signal on the block signal, a special line relay is added to the caution signal, the current (supplied by the block signal battery) of which should pass by con-

Fig. 11. — Automatic block signal in the « clear » position.

Fig. 12. — Automatic block signal in the « stop » position.

Fig. 13. — Automatic block caution signal in the « Pass, line clear » position.

Fig. 14. — Automatic block caution signal repeating the block signal in the « stop » position by the indication : « Pass at reduced speed ».

tacts controlled by the signal arm of the block signal. These contacts are closed when the block signal is at clear. The operating gear of the caution signal arm receives its current through the contact of the special line relay. This current is given by a special battery near the caution signal. The caution signal takes rather more current than the other (up to 2.8 amperes) and requires seven to eight seconds to go to the clear position. (The angular deplacement to be made is double that of the block signal.) To fall back from the off position takes three to four seconds.

In America generally the operating gear of the block signal used gives three positions : horizontal arm indicating the stop, the arm at 45° upwards, the pass at reduced speed, and the arm vertically upwards, line clear. (These are known as « upper quadrant » indications as opposed to the « lower quadrant » indications with horizontal, 45° down, and vertically downwards, positions.)

With this system the caution signal is really useless, provided of course, a signal gives the indication « pass at reduced speed » when the following signal is at danger. It is also necessary that the distance between signals should not be too great. With the three-position signal in the case of the automatic block an interesting method of erection, using polarised relays (without line current), to ensure the dependence of the signals on each other can be adopted.

A relay of this kind has a polarised armature with contacts in addition to the usual neutral armature with contacts. The track battery current passes through the pole changing contacts of the arm operating gear. When a signal is set to clear (and also when set to pass at reduced speed) the direction of the current in the insulated track in front of this signal, is opposite to that of the current flowing when the signal is put to danger. The polarised armature of the track relay for this part of the track depends upon it. The contacts either drawn together or left apart allow the preceding signal to go to clear or to caution, if, of course, the part of the line concerned is unoccupied, this being controlled by the neutral armature of the track relay.

* * *

The line relays are similar in construction to the track relays except that the resistance is 630 ohms and the consumption $\pm$ 10 milliamperes : they are put in small relay cupboards carried on the signal post. The line relays of the block signals receive current from the following block signal battery through the contacts of the track relays lying between the two signals affected.

The conductor wires from the battery cellars are carried through the foundation of the signal post into the Mannesmann tube, then pass into the cupboard in which the relays are fitted from which they are again carried up inside the tube to the operating gear.

* * *

The Gouda-Oudewater section is divided into four blocks. The first and last are special blocks in the sense that they have to allow trains to pass from the automatic block to the ordinary block and vice versa, and this in the Gouda and Oudewater stations.

The subdivision into four blocks remains the same as with the ordinary block as there was no special reason for making a change. It should, however, be added that in a section with heavy traffic, it is of great advantage to be able readily to subdivide the line into a number of block sections. The more blocks there are, the more signals there will be : but as it is necessary to insulate the whole track and fit it with electric circuits, a block more or less has less effect on the total cost than in the case of the ordinary block.

The Gouda-Oudewater case, by making it possible with its four succeeding block sections to do away with the staff of three block posts, has been very profitable for Holland. Most often, the distance between two consecutive stations can itself be used as the length of block, or is such that one or two block posts at most can be established in it.

A line wire has been used for each direction, insulated wire being used, whereas for the two directions an old bare block wire (existing telephone wire) has been used as common return wire. This last wire will be replaced by an insulated wire when renewing the wiring. For the circuits of the line relays of the caution signals, an insulated line has been laid between the block signal and the caution signal, and for the return a common wire has been used. All connections are made with two wires.

Another existing block line is used as telephone line with telephonic apparatus at Gouda, at Oudewater and near the three intermediate signals. By means of this installation the train staff can ask for instructions, as it should always do in foggy weather should the signal be found at danger.

Immediately after the automatic block signals short lengths 300 m. (328 yards) of insulated track have been provided.

In this way what is known as a signal overrun allowance has been provided.

In Holland usually this overrun of the block signal is usually made equal to 100 m. (109 yards), provided this signal is preceded by a caution signal and a special indicator in case of fog. In America no such allowance is made at all : a stop signal is a point at which a train must definitely stop. It is therefore placed just before the danger point, or rather 10 to 20 m. (11 to 22 yards) before it. In other words, the overrunning allowance is none the less 10 to 20 m., and the block preceding a signal stops 10 to 20 m. behind the signal admitting into the following block. This distance serves solely to prevent the signal which is at clear, for example, from falling to stop in the face of the driver when the first wheel of the locomotive enters the section.

According to the practice in Holland, a distance of at least 100 m. (109 yards) has to be provided. It happens, however, that this distance does not belong to the block protected by the signal just before it, but to the block protected by the preceding one. It is therefore possible that a short train (locomotive, uncoupled wagons, etc.) should find itself in the allowed overrun, and that the signal at the beginning of this part of the track might give line clear. Although the preceding signal would be at danger (the short train above always in reality being in its block section) the situation described above could not be admitted as it was essential that a train after having stopped at an automatic signal at danger should be able to pass it by proceeding at caution (shewn by the letter V = voorzichtig = caution, on the relay armature, fig. 12). The problem was solved by insulating the length of the track constituting the allowed overrunning distance (extended here for safety to 300 m. [328 yards]), and making the signal which is placed just before it dependent upon its non-occupation, just like the preceding signal which commands the entry into the block of which the overrun really forms part.

In the case of figure 4 without line circuit, the presence of an overrun makes the use of a small line circuit necessary. The length of this auxiliary line circuit should equal that of the allowed signal overrun. In effect, the supply of current for the relay of the insulated part of the overrun would depend, in the energised position, upon the other track relays of the block considered. In making the preceding signal dependent on this relay, this signal is made dependent at the same time on the whole of the second block, etc. For this reason the over-

run relay ought to be made independent of the following relays. It is, however, necessary to control the position of the first following relay by the block signal. We get in this way a chain of line relays in which we find the contacts of the overrun relays and of the first track relay following which, in itself, depends on the state of the whole of the block to which it belongs.

As we have already said, in America the falling of the signal arm to stop, as soon as a train enters into the block, is relied upon absolutely and all control is dispensed with. In the German connections this control is always found by the fact that the shutting off the current for a signal after a train depends, not only on the train leaving the block, but also upon the following signal being put to stop. This method of working has the drawback that if, for example, a trolley in the block is taken off the line, the following block is not occupied, and the signal following in consequence is not at stop. It follows that the first signal can only go to clear when the following train, after having needlessly stood in front of this signal, continues its journey into the second block.

At Gouda-Oudewater the placing of a block signal to clear has been made to depend upon the following block signal falling to danger, by inserting in the line relay circuit of the first signal a contact which closes when the following signal is at stop. In addition to this, in parallel with this contact, is coupled another contact depending on the line relay of the following signal. When this signal does not fall to stop, the first signal can only go to clear when the relay is energised. This occurs when the train leaves the second block. The first signal acts for the signal out of order and then protects two blocks. If now a trolley enters the block and is lifted off the line, the following line relay remains energised and the signal again returns to clear. Although with this system the drawbacks of the German method are overcome, it is none the less true that the connections have become more complicated, and consequently the danger of getting out of order has increased. By making the blocks depend one upon the other, a failure in one of them is transmitted at once to the others.

* * *

The change from the automatic block to the ordinary block is carried out as follows. The automatic block ends with the length of insulated track acting as overrun of the signal preceding the signal at the entrance to the station. In order that the relay of this part of the track may receive current, it is not only necessary that this part of the line be unoccupied, but also that the entrance signal be at danger, that is to say, that the train is protected in the station. As soon as the relay is energised it becomes independent of the signal.

The line relay of the last block near a station is, so to speak, divided into two relays, each having half the resistance. The first continues to fill the role of line relay, and ought then to close the circuit or cut off the current for the last automatic block signal before the station. The second acts as a warning relay for the station. As soon as a train enters the block, the relay lifts and a bell continues to ring at the signal box until the train leaves the block and the signal has been set to stop.

The passage from the ordinary to the automatic block is made with the assistance of an electro-magnet for putting the signal to danger, which when energised couples the operating gear and the signal arm together. This electro-magnet can only receive current under certain conditions, such as for example, when the line relay of the automatic block is energised, that is to say, when this block is clear. (This relay serves at the same time as a warning when a train has left

the block.). As soon as a train enters the block the signal falls to danger. As a matter of interest, a similar electro-magnet is also used to make the train itself cause a mechanically operated signal to fall to stop. (In this way a semi-automatic signal is provided). When this is done, the signal cannot again be set to clear until the signal lever has been restored to its original position.

To put the signal to clear, it is then necessary for the electro-magnet to receive further current and for the lever to be pulled once again. If the lever is handled without current going to the electro-magnet, the arm will not follow it and the signal will remain at stop.

***

As regards the different kinds of cable used, we have adopted :

for the connections between the rails : copper wire 4 mm. (0.157 inch) diameter with tinned conical plugs driven by hammer into 9/32 inch holes;

for the insulated wires carried on the telegraph poles used to carry the line current for the block and warning signals : copper wire known as « Hard-drawn double-braided weatherproof » of 2.5 mm. diameter (0.098 inch);

for the connections of the relay cupboards to the operating gear of the arm : vulcanised insulated wire 2.5 mm. (0.098 inch) and 1.6 mm. (0.063 inch) in diameter;

for the connections of the relay cupboard to the tubes holding the track batteries : flexible insulated vulcanised wire 2.5 mm. (0.098 inch) in diameter;

for the connections in the relay cupboards : flexible insulated vulcanised wire 1.3 mm. (0.051 inch) in diameter;

for the connections of the relays and batteries to the rails : armoured vulcanised twin wire cable;

and for the connections, like those from the battery pits to the signals : flexihle vulcanised cable with seven wires.

There are in service a total of thirty-two track batteries, each having two cells in parallel, and fourteen signal batteries, each with sixteen cells in series, two of these batteries being at Gouda and Oudewater for the line relays, electro-magnets for setting to stop, etc. On an average a service of two-thirds of a year is expected from the track batteries before renewing the combined poles and the liquid : from the block signal batteries a year is expected, and from those of the caution signals, two years.

***

In order to draw attention to the great importance of a defect in the copper wires forming an electric joint conductor at the ordinary fish plates, a fault that occurred during the trial period of the automatic block on the Gouda-Oudewater line may be described.

It will be understood that before putting the automatic block definitely into service, it was tested in use during two months. It was during this period that all the electrical measurements of which we have spoken were made.

In order to conceal the signal arms from the drivers, a wood frame was placed in front of them. The back of the arm alone was visible when they looked back after passing the signal. (They did this always in order to see if the signal had fallen to danger.)

During this period a curious fault occurred which was only localised after much search. It was due to the copper wire bonding an ordinary fish plate joint having become broken at a level crossing by the road traffic. These wires were most of the time sufficiently in contact to pass the current required to work the apparatus. Sometimes however owing to the movement of vehicles using the crossing, they separated and a failure occurred.

At the time the defect was discovered the wires were actually in contact, and

the extraordinary thing was that when they were separated the track relay affected remained in the energised position and no failure occurred : that is to say, sufficient current remained to operate this relay. After imitating the passage of a train by artificially short circuiting the rails, the relay released the contacts, but when subsequently, the short circuiting connection was broken, the relay did not operate again. The failure had been reconstructed.

The tension between the rails was, with the copper wires in perfect contact, the same before the joint as beyond it, and was 0.5 volt. When the wires were separated it was 0.5 volt in front of and 0.25 volt beyond the joint.

The above shews that all the details of the automatic block must be thoroughly well maintained and inspected. The use of connections with double wire has therefore not been an unnecessary precaution.

To prevent the electric wires breaking at the rail joints at level crossings, the 12 m. (40 ft. 5 1/2 in.) rails have been replaced by rail 18 m. (59 ft. 5/8 in.) long wherever it was considered desirable.

APPENDIX.

Notes upon the relation existing between the insulation resistance of an insulated track, the resistance of the electric conductors leading to it, and the electromotive force of the battery used.

The connections of an insulated rail or of an insulated track are shewn diagrammatically in figure 15.

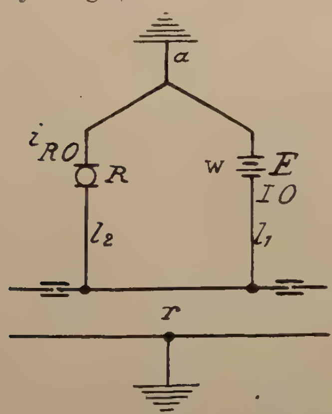


Fig. 15.

Let :

- a, be the resistance of the ground,
- R, be the resistance of the track relay,
- l_1 and l_2 be the resistance of the electric wires,
- r, be the insulation resistance of the track,
- E, be the voltage of the battery,
- w, be the internal resistance of the battery,
- I_0 be the intensity of the current supplied by the battery when the line is unoccupied.

I_0 divides into two parts : 1. i_{R0} passing by the relay ; 2. that passing by the insulated track. The whole of the leakage currents through the earth occurring all along the track is supposed to be collected in an electric circuit of a resistance of $r + a$. No account will be taken of the potential difference between the ends of the rails, in other words, the resistance of the rails plus the connections to the joints will be ignored. In the case of tracks, even of great length, with copper electric bonding wires carefully fitted, this approximation is amply sufficient.

If the resistance of the two branches is represented by b, we have :

$$I_0 = \frac{E}{w + l_1 + b} \quad \text{in which} \quad \frac{1}{b} = \frac{1}{r + a} + \frac{1}{R + l_2}$$

whence

$$I_0 = \frac{E}{w + l_1 + \dfrac{(r + a)(R + l_2)}{r + a + R + l_2}} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Furthermore we have $I_0 b = i_{R_0}(R + l_2)$ which gives when developed :

$$I_0 = \frac{i_{R_0}(r + a + R + l_2)}{r + a} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Combining (1) and (2) we get :

$$E = i_{R_0}\left\{\frac{(w + l_1)(R + l_2)}{r + a} + w + l_1 + R + l_2\right\} \quad \ldots\ldots\ldots\ldots \quad (3)$$

If in any particular case we wish to find by equation (3) the electromotive force of the battery, E and w will be the unknowns, whilst the other values are either known or can be determined experimentaly.

Let i_{RB} indicate the intensity of the current in the branch of the relay in the case of track occupied. In this instance r is practically nil.

Equation (3) then becomes :

$$E = i_{RB}\left\{\frac{(w + l_1)(R + l_2)}{a} + w + l_1 + R + l_2\right\} \quad \ldots\ldots\ldots\ldots \quad (4)$$

Taking :

n, the number of cells of the battery coupled in series,

m, the number of cells of the battery coupled in parallel,

e, the electromotive force of a cell,

w_1, the internal resistance of a cell.

Then $E = ne$ and $w = \dfrac{n}{m} w_1$

It should be noted that for any particular kind of cell, m depends solely on the intensity of current to be supplied by the battery.

Taking furthermore $l_1 = l_2 = l$, equation (3) becomes :

$$ne = i_{R_0}\left\{\frac{\left(\dfrac{n}{m} w_1 + l\right)(R + l)}{r + a} + \frac{n}{m} w_1 + R + 2l\right\}$$

Whence

$$n = \frac{i_{R_0} m \left\{ l(R + l) + (R + 2l)(r + a) \right\}}{(r + a)(em - i_{R_0} w_1) - i_{R_0} w_1 (R + l)} \quad \ldots\ldots\ldots\ldots \quad (5)$$

This equation will give n in each particular case. Knowing n the value of i_{RB} can be got from equation (4) and should be sufficiently small for the relay not to be energised in the case of line occupied.

Although the above was found to take place in the case of an insulated track at Amsterdam W. P., the desired result is not obtained blindly. When considering equation (5) it will be remarked, with existing proportions (that is $n > 0$), that n increases when l increases, whilst if r diminishes, n increases further. The denominator of the fraction (5) diminishes

notably when l increases, whilst the numerator increases : when r diminishes, the denominator diminishes more than the numerator. The values of the other terms of equation (5) depend entirely on the relay and the sort of battery used : they may consequently be taken as constant.

In the case of large values of l and of small values of r abnormal proportions may be obtained.

* * *

The insulated track in question in Amsterdam W. P. had a length of about 260 m. (284 yards). The value of $r + a$ in wet weather after several days continuous rain was found to be 3 ohms. This figure is very low : the track was therefore in bad condition. The value of a was 0.5 ohm which gave $r = 2.5$ ohms; l was equal to 8.3 ohms. The resistance of the relay was 6.5 ohms, whilst i_{R0} was 0.15 ampere.

As it was here a question of the ordinary block, the battery had to supply current during short intervals of time only : Leclanché cells were considered good enough on account of their moderate cost. Taking

$$e = \pm 1.25 \text{ volts} \quad \text{and} \quad w_1 = 2 \text{ ohms.}$$

When the total current to be supplied by the battery in the case of line unoccupied is determined from equation (2) we get $I_0 = \pm 0.9$ ampere.

This very high value results in $m = 4$. The equation (5) then gives the value $n = 12$, so that $n \times m = 48$ cells.

Starting from these figures, and calculating the intensity of current through the relays with line occupied, we get $i_{RB} = \pm 0.03$ ampere which is low enough seeing that with this relay we can use $\pm$ 0.075 ampere whilst I_B, the total intensity in the case of line occupied can reach $\pm$ 1 ampere.

These results were very unexpected but agreed perfectly well with the actual amounts obtained. For this reason the electric measurements continued to be made using dry cells for which m can equal 1, and $e = 1.5$ volt with $w_1 = 0.15$ ohm.

Based upon these values we find $n = 8$ (whilst $i_{RB} = 0.035$ ampere, $I_0 = 1$ ampere, and $I_B = 1.2$ amperes).

These figures also agreed with the actual results obtained.

* * *

The result of the above calculations was that a very powerful battery had to be used. As we have already said, the causes were the high value of l and the low value of r which gave a bad proportion between the resistance of the branch with the relay and that of the insulated track.

Of the 0.9 ampere given by the Leclanché battery, 0.15 ampere only passed to the relay, the remainder leaking away through the track.

* * *

If the problem is considered more deeply, and for the sake of simplicity $r + a$ is taken as $= d$,

equation (5) can then be written :

$$n = \frac{i_{R_0} m \left\{ l (R + l) + (R + 2l) d \right\}}{d (em - i_{R_0} w_1) - i_{R_0} w_1 (R + l)}.$$

As we have already seen, when l increases, n also increases, and if $d = r + a$ diminishes, n increases, of course be it understood for a given battery and relay.

Let us lay down the condition that the battery cannot exceed a certain size ; equation (5) will then represent the relationship between l and d for the most powerful battery that can be allowed. For any given value of d the largest permissible value of l can be got from it, and reciprocally for any given size of l, the smallest allowable value of d can be deduced.

If equation (5) be resolved in regard to d, we get :

$$d = \frac{i_{R_0} m l^2 + (i_{R_0} m R + n i_{R_0} w_1)\, l + n i_{R_0} w_1 R}{nem - n i_{R_0} w_1 - i_{R_0} m R - 2 i_{R_0} m l} \qquad (6)$$

If we resolve it for l we shall get :

$$l^2 + \frac{i_{R_0}mR + ni_{R_0}w_1 + 2i_{R_0}md}{i_{R_0}m}\, l - \frac{(nem - ni_{R_0}w_1 - i_{R_0}mR)\, d - ni_{R_0}w_1 R}{i_{R_0}m} = 0. \quad (7)$$

From equation (6) $d_{max.}$ becomes ∞ when

$$nem - ni_{R_0}w_1 - i_{R_0}mR - 2i_{R_0}ml = 0$$

or

$$l_{max.} = \frac{nem - ni_{R_0}w_1 - i_{R_0}mR}{2i_{R_0}m},$$

whereas for $l_{min.} = 0$, we shall get :

$$d_{min.} = \frac{ni_{R_0}w_1R}{nem - ni_{R_0}w_1 - i_{R_0}mR},$$

or again

$$d_{min.} = \frac{i_{R_0}w_1R}{em - i_{R_0}w_1 - \dfrac{i_{R_0}mR}{n}}.$$

So that the limiting values of l and of d may be calculated the limiting battery selected was composed of $n \times m = 12$ Leclanché cells

Provisional estimates of the total resistances $W_{min.}$ and $W_{max.}$ through which the battery should supply current (checked subsequently by the actual figures obtained) resulted in the values of e used being those given in the following table, the other figures of the table being calculated from them.

	$m = 1$ $n = 12$	$m = 2$ $n = 6$	$m = 3$ $n = 4$	$m = 4$ $n = 3$	
$d_{min.}$ (for $l = 0$), in ohms.	2 ($e = 1.33$)	1.2 ($e = 1.13$)	$\pm$ 1 ($e = 0.97$)	$\pm$ 1 ($e = 0.85$)	$n \times m = 12$.
$l_{max.}$ (for $d\,\infty$), in ohms.	40 ($e = 1.39$)	21 ($e = 1.37$)	13.5 ($e = 1.35$)	9 ($e = 1.33$)	$w_1 = 2$ ohms. $R = 6.5$ ohms. $i_{R_0} = 0.15$ ampere.
$W_{min.}\,0$ (for $l=0$), in ohms.	25.5	7	3.6	2.5	
$I_{max.}\,0 = \dfrac{E}{W_{min}\ 0}$, in amperes	0.63	1	1.08	1.04	
$W_{max.}\,0$ (for $d\,\infty$), in ohms.	110	55	36	26	
$I_{min.}\,0 = \dfrac{E}{W_{max.}\ 0}$, in amperes	0.15	0.15	0.15	0.15	

These calculations shew how much the reduction of the value of l increases the useful value of the cells, even when Leclanché cells are used.

The fact of placing the battery and the relay near the track allows the length of the insulated track to be considerably extended.

When $l = 0$, the intensity of the current is, however, such that the three first columns of the table cannot be taken into consideration : it is only after $m = 4$ that the figures approach those applicable in practice.

Calculations and use in service both prove that Leclanché cells are not suitable for this purpose : for this reason small batteries of accumulators have been used for many years.

Let us again for comparative purposes calculate the values of $d_{\text{min.}}$ and $l_{\text{max.}}$

Taking $e = 1.8$ volts, the internal resistance can be ignored so that $w = 0$. The equations (3) and (4) then become :

$$E = i_{R_0} \left\{ \frac{l_1 (R+l_2)}{r + a} + l_1 + R + l_2 \right\}$$

and

$$E = i_{RB} \left\{ \frac{l_1 (R + l_2)}{a} + l_1 + R + l_2 \right\},$$

or again making :

$$E = ne : l_1 = l_2 = l \text{ et } d = r + a :$$

$$ne = i_{R_0} \left\{ \frac{l (R + l)}{d} + 2\, l + R \right\} \quad \ldots\ldots\ldots\ldots\ldots \quad (8)$$

and

$$ne = i_{RB} \left\{ \frac{l (R + l)}{a} + 2\, l + R \right\} \quad \ldots\ldots\ldots\ldots\ldots \quad (9)$$

Developing (8), we get :

$$d = \frac{i_{R_0} l (R + l)}{ne - i_{R_0} (2l + R)} \quad \ldots \quad (10)$$

When l increases in this equation d also increases, and reciprocally. When $l = 0$, no value can be got for $d_{\text{min.}}$, as the internal resistance of the battery is nil. To get $d_{\text{min.}}$ we ought to start with equation (9). When l increases in this equation, i_{RB} diminishes, and reciprocally. When we now introduce $i_{RB\,\text{max.}} = 0.075$ ampere we can obtain the smallest allowable value of l.

To do this, let us put equation (9) into the following form :

$$l^2 + (R + 2a)\, l - \left(\frac{ne}{i_{RB}} - R\right) a = 0.$$

Having found $l_{\text{min.}}$ we can get $d_{\text{min.}}$ from equation (10).

Equation (10) gives also for $d_{\text{max.}}$ the value of ∞ when

$$ne = i_{R_0} (2l + R)$$

or

$$l_{\text{max.}} = \frac{ne - i_{R_0} R}{2 i_{R_0}}.$$

By means of these different equations the table below has been calculated :

	$n = 1$	$n = 2$	$n = 3$	$n = 4$	$n = 5$	
$l_{\text{min.}}$ (for $i_{RB\,\text{max.}}$), in ohms.	1	2.15	3.1	4	4.7	$I_{\text{max. 0}}$ varies for $n = 1 \ldots\ldots 5$ from 0 65....1.5 amperes, whilst $I_{\text{max. B}}$ (that is to say, the maximum current intensity the battery has to supply with line occupied) varies from 1.2.....1.8 amperes.
$d_{\text{min.}}$ (for $l_{\text{min.}}$), in ohms.	2.3	1.4	1.3	1.25	1.2	
$l_{\text{max.}}$ (for $d\ \infty$), in ohms.	2.7	8.7	14.7	20.7	26.7	

The case already dealt with, Amsterdam W P , gave with a battery of accumulators for equation (8) $n = \pm 5$, whilst the intensity of current with line occupied $I_B = \pm 1$ ampere. The result is much more satisfactory than with Leclanché cells.

Instead of starting from $l_{min.}$ to prevent i_{RB} becoming more than 0.075 ampere, a resistance is inserted in front of the battery (fig. 16).

The equations (3) and (4) then become ($l = 0$ et $w = 0$)

$$E = ne = i_{R_0}\left(\frac{xR}{d} + x + R\right) \quad . \ . \ (11)$$

and

$$E = i_{RB}\left(\frac{xR}{a} + x + R\right) \quad . \ . \ . \ (12)$$

When x diminishes, d also falls, whereas i_{RB} increases, then x is a minimum when $i_{RB} = 0.075$ ampere. The following table gives the values of $x_{min.}$ thus calculated with the corresponding values of $d_{min.}$

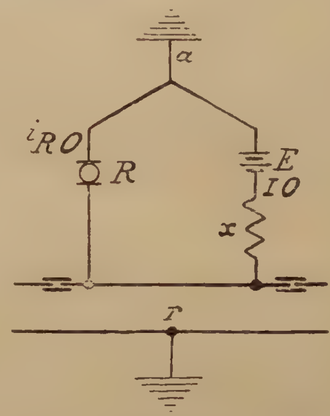


Fig. 16.

	$n = 1$	$n = 2$	$n = 3$	$n = 4$	$n = 5$	
$x_{min.}$ (for $l = 0$ and i_{RB} max.), in ohms	1.3	3.1	4.9	6.7	8.5	$I_{max.\,0}$ varies in these cases from 0.6 ... 0.95 ampere, whilst $I_{max.\,B} = 1$ ampere.
$d_{min.}$ (for $x_{min.}$), in ohms .	2.15	1.5	1.35	1.29	1.26	

The layout of the connections with a resistance x at the battery from the point of view of the supply of current from the battery is therefore better than that with a $l_{min.}$, whilst the values of $d_{min.}$ remain about the same

* * *

When the value of l is less than that given for $l_{min.}$ in the last table but one, a resistance x must be introduced as otherwise i_{RB} becomes too great.

If further $l > 0$, the last two cases combine.

The equations (3) and (4) then become ($w = 0$) :

$$E = ne = i_{R_0}\left\{\frac{(l + x)(R + l)}{d} + 2l + x + R\right\} \ (13)$$

and

$$E = i_{RB}\left\{\frac{(l + x)(R + l)}{a} + 2l + x + R\right\} \ (14)$$

For values of l less than $l_{min.}$ we can deduce from equation (14) the minimum value of x to prevent i_{RB} becoming greater than 0.075 ampere, whereas with this $x_{min.}$ we can get from equation (13) the minimum value of d, for which i_{R_0} is still equal to 0.15 ampere. Attention should be called to the fact that in the tables given above it is always a question of theoretical limiting values, that is to say :

1. to determine $d_{min.}$:

when : $l = 0$ or with $l_{min.}$

or when : $l = 0$ with an $x_{min.}$

or when : $l < l_{min.}$ with a suitable $x_{min.}$

2. to determine $l_{max.}$ with $d = \infty$.

All actual cases in practice are included within these limits.

* * *

As an example of these calculations for an accumulator battery, we will select the very frequent case of the 30-volt battery used by the Netherland Railways in the ordinary block for insulated lines.

The layout of the connections is that shewn in figure 17. These connections are the same as those of the automatic block except that the battery and the relay are placed in the corresponding block section hut, and there may therefore be large resistances l. In addition, the battery and the non-insulated rail are earthed.

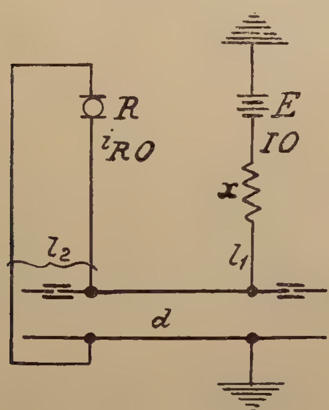


Fig. 17.

This arrangement is safer than that of figure 16, as all the connections to the rails in the relay circuit are controlled. With scheme (fig. 17) the quantity a is brought into the equation in quite a different way.

The best that can be done is to include a in the value of l_1 by supposing that instead of the earth there is a return wire (which has the sole effect of increasing the value of l_1) as is done in the automatic block and on the sections of electrified railways. The preceding equations then become applicable, provided we take $d = r$.

By doing this, all the equations and calculations of i_{RB} can no longer be used because with line occupied the train is supposed to make a complete short circuit.

It is, however, necessary to take into account a certain value of i_{RB} and a. It is sufficient if a is considered as the insulation resistance of the track when it is occupied, d when unoccupied, and r as the difference between d and a. If then we take for l_2 the resistance of the outward and return conductors, and for l_1 the resistance of the conductor in question + the resistance of the earth (or if not earthed the resistance of the outward and return conductors) the equations and calculations already given remain applicable.

We will suppose that with the $\pm$ 30-volt battery, the 6.5-ohm relay is used, although in the case we are considering the 18-ohm relay with a i_{R_0} of $\pm$ 0.14 ampere is used in preference.

This hypothesis will allow us the better to compare the various results obtained with one another. If we again suppose $a = 0.5$ ohm, we should get in the preceding table $l_{min} = 11$ ohms with $n = 17$.

Let us now take, for example, $l_2 = 10$ ohms and provisionally allow with a view to calculating the minimum values that $l_1 = l_2 = l = 10$ ohms. This is the same as saying that the battery also possesses outward and return conductors, or that the relay wires are doubled, or again that the distance from the relay to the track is less than that of the track battery.

A resistance x must then be inserted near the battery.

The equation (14) gives :

$$x = \frac{\frac{Ea}{i_{RB}} - \left\{ l\,(R + l + 2a) + Ra \right\}}{R + l + a} \qquad (15)$$

The equation (15) gives for $i_{RBmax.}$ a value of $x_{min.} = 1.3$ ohms.

The equation (13) gives :

$$d = \frac{i_{R_0}(l + x)(R + l)}{E - i_{R_0}(2l + x + R)} \quad . \; . \; . \; (16)$$

Equation (16) gives for $x_{min.}$ a value of $d_{min.} = 1.1$ ohms.

With these values we could still work with an insulation resistance of ± 1 ohm. The current intensity in the battery would then be given by equation (1) with $w = 0$, $l_1 = l + x$ and $r + a = d$:

$$I_0 = \frac{E}{(l + x) + \dfrac{d(R + l)}{d + R + l}} \quad . \; . \; (17)$$

Whence $I_0 = 2.5$ amperes.

In favourable cases in which insulation resistances greater than 1 ohm are found, a greater resistance x is introduced, and if we allow for d a value of say 5 ohms, equation (13) gives :

$$x = \frac{\dfrac{Ed}{i_{RB}} - \left\{ l(R + l + 2d) + Rd \right\}}{R + l + d} \quad (18).$$

whence

$x = 33$ ohms (with $d = 5$ ohms).

In reality it does not matter if l_1 equals l_2 because if l_1 is smaller than l_2 it is only necessary to subtract the difference from x, and if l_1 is greater than l_2, to add it to x to arrive at in the end the true value of x.

If I_0 is now calculated, we get $I_0 = 0.66$ ampere, a value differing appreciably from that obtained for I_0 relative to d_{min}.

* * *

The following remarks may be made on the numerical values selected. It is unusual to find conductor wires with a resistance exceeding 20 ohms. If the case should occur it would be desirable to double the wires of the relays so as to diminish the resistance, which would also be very well worth doing for smaller values of l.

All the calculations made shew the great influence of the resistance of the conductor wires. The intensity of the current required for the operation of the apparatus falls off considerably when l diminishes. The most favourable case from this point of view is that in which the relay is placed beside the track.

When operating in this way : theoretically $l = 0$: it is more accurate, however, to introduce into the calculation a small value for l, such as $l = 0.5$ ohm. The whole of the equation can then be used, on condition of subtracting from the value for x the resistance of the wires to the batteries (less 0.5 ohm) so as to find the true value of the resistance to be introduced (the battery being supposed to be placed near the track).

The values $d = 10$ ohms and $d = 5$ ohms can then be considered as being the low limiting values for an insulated rail and for an insulated track respectively.

* * *

Let us now pass to the automatic block in which the relay and the battery are placed near the track (fig. 18). The equations established for the case of figure 17 are applicable to the case of figure 18 when l is taken $= 0.5$ ohm.

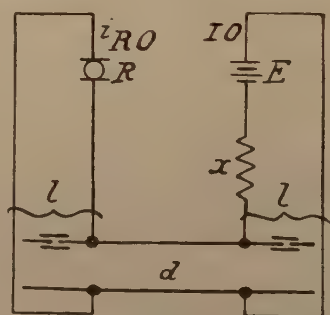


Fig. 18.

The other values for the Gouda-Oudewater line are :

$i_{RO} = 0.1$ ampere (taken a little on the

$l = 20$ ohms.	and $E = 30$ volts.

			(unoccupied) $d = 10$ ohms.			(unoccupied) $d = 5$ ohms.			(occupied) $d = a = 0.5$ ohm.	
Relay (R in ohms).	i_{R_0} in amp.	i_{RB} max. in amp.	x in ohms.	I_0 in amp.	i_{RB} in amp.	x in ohms.	I_0 in amp.	i_{RB} in amp.	$x_{min.}$ in ohms (for i_{RB} max.)	$d_{min.}$ in ohms (for $x_{min.}$)
ohms.	± 0.15	± 0.075	29	0.54	0.014	7.5+	0.95	0.02	0^+ (negative)	3.5
ohms	± 0.14	± 0.07	17	0.67	0.01	0.5+	1.2	0.017	0^+ (negative)	5
ierican relay : 4 ohms . .	0.09	0.03	71	0.3	0.007	33.5	0.52	0.012	0^+	1.1 (1.66)
ierican relay : 9.2 ohms .	0.063	0.021	94	0.25	0.004	45	0.43	0.008	3.5^+	1.1 (1.6)
ierican relay : 16 ohms. .	0.045	0.015	117	0.21	0.003	57	0.37	0.006	7^+	1.1 (1.6)
nerican relay : 55 ohms. .	0.027	0.009	102	0.23	0.002	45	0.43	0.003	1.6	1.1 (1.6)

$l = 10$ ohms	and $E = 30$ volts.

			(unoccupied) $d = 10$ ohms.			(unoccupied) $d = 5$ ohms.			(occupied) $d = a = 0.5$ ohm.	
Relay (R in ohms).	i_{R_0} in amp.	i_{RB} max. in amp.	x in ohms.	I_0 in amp.	i_{RB} in amp.	x in ohms.	I_0 in amp.	i_{RB} in amp.	$x_{min.}$ in ohms (for i_{RB} max.)	$d_{min.}$ in ohms (for $x_{min.}$)
5 ohms.	± 0.15	± 0.075	60	0.4	0.013	33	0.66	0.02	1.3^+	1.1
ohms	± 0.14	± 0.07	39	0.53	0.009	18	0.93	0.019	0^+ (negative)	1.6
nerican relay : 4 ohms . .	0.09	0.03	123	0.216	0.008	74	0.34	0.013	24	± 1.1 (1.7)
nerican relay : 9.2 ohms .	0.063	0.021	147	0.182	0.005	85	0.31	0.008	26	1.1 (1.65)
merican relay : 16 ohms. .	0.045	0.015	168	0.163	0.004	93	0.28	0.006	27.5	1.1 (1.6)
nerican relay : 55 ohms. .	0.027	0.009	130	~~0.2~~	~~0.002~~	65	0.38	0.003	15	1.1 (1.6)

The values of x marked by a cross + are not high enough for it to be possible later on to subtract $1/2\, l_2 = 10$ ohms, vhen for example we actually get $l_1 = \pm 1/2\, l_2$ (when the relays and batteries alone are earthed).

$l = 0.5$ ohm.	and $E = 30$ volts.

			(unoccupied) $d = 10$ ohms.			(unoccupied) $d = 5$ ohms.			(occupied) $d = a = 0.5$ ohm.	
Relay (R in ohms).	i_{R_0} in amp.	i_{RB} max. in amp.	x in ohms.	I_0 in amp.	i_{RB} in amp.	x in ohms.	I_0 in amp.	i_{RB} in amp.	$x_{min.}$ in ohms (for i_{RB} max.)	$d_{min.}$ in ohms (for $x_{min.}$)
5 ohms	± 0.15	± 0.075	113	0.25	0.018	80	0.36	0.025	26	1.1
ohms	± 0.14	± 0.07	68	0.4	0.012	41	0.66	0.019	10	1.05
nerican relay : 4 ohms . .	0.09	0.03	226	0.13	0.013	173	0.17	0.017	99	1.25 (1.9)
merican relay : 9.2 ohms .	0.063	0.021	237	0.127	0.006	158	0.18	0.01	69	± 1.1 (1.7)
nerican relay : 16 ohms. .	0.045	0.015	244	0.12	0.004	151	0.195	0.006	58	1.1 (1.6)
merican relay : 55 ohms. .	0.027	0.009	161	0.176	0.002	87	0.325	0.003	29	1.1 (1.6)

The values taken for i_{R_0} and i_{RB} max. in the case of the 6.5 and 18-ohm relays do not give the same feeling of onfidence as for the other relays.

It should be noted that for the numbers for $d_{min.}$ in brackets in the American relays the current intensity for the vhole service which is 50 % greater than that just required to energise the relay is taken into account.

high side for safety); $R = 4$ ohms; $E = 0.6$ volt (1 caustic soda cell, the internal resistance of which is negligible).

We can again use the equation (16):

$$d = \frac{i_{R_0}(l + x)(R + l)}{E - i_{R_0}(2l + x + R)}.$$

In order to determine the minimum insulation resistance of the track we may put $x = 0$, whence

$$d_{\text{min.}} = \frac{0.1 \times 0.5 \times 4.5}{0.6 - 0.1(1 + 4)} = 2.25 \text{ ohms.}$$

From equation (17) when $x = 0$, we obtain

$$I_0 = \frac{E}{l + \dfrac{d(R + l)}{d + R + l}} = 0.3 \text{ ampere.}$$

Calculating I_B for absolute short circuit, we have

$$I_B = \frac{E}{l} = 1.2 \text{ amperes.}$$

Let us calculate $a_{\text{max.}}$, that is to say, the maximum admissible value of the insulation resistance in the case of line occupied which, in other words, is the same as calculating the maximum allowable imperfectness in short circuiting by the wheels and axles of the train.

If we make $i_{RB\,\text{max.}} = 0.03$ ampere and $x = 0$, equation (16) then gives

$$a_{\text{max.}} = \frac{i_{RB}\, l(R + l)}{E - i_{RB}(2l + R)} = 0.15 \text{ ohm.}$$

As we have already said, the short circuit caused by a train is in reality such that little current passes through the relay.

The insulated tracks at Gouda-Oudewater having under the most unfavourable cases lengths of 900 m. (984 yards) and an insulation resistance of 4 to 6 ohms in wet weather, it will be seen that there is a large margin in relation to the calculated minimum of 2.25 ohms. Furthermore, the intensity of current through the relay has the value of 0.1 ampere, which is also sufficient.

It must be added, however, that before the values can be definitely accepted as correct, the tests must be repeated under the most unfavourable conditions possible.

For the most unfavourable track of 4 ohms we can then calculate the value of x by means of equation (18).

$$x = \frac{\dfrac{Ed}{i_{R_0}} - \left\{ l(R + l + 2d) + Rd \right\}}{R + l + d} = 0.21 \text{ ohm.}$$

whilst equation (17) gives $I_0 = 0.212$ ampere.

Calculating I_B with complete short circuit we find $I_B = 0.84$ ampere.

If a resistance $x = 0.21$ ohm is introduced, we get $a_{\text{max.}} = 0.22$ ohm.

As a comparison, in America an inefficient short circuit of 0.06 ohm is allowed so that the values used on the Gouda-Oudewater line are sufficiently safe, even taking into account the fact that the American rolling stock is heavier than that used in Holland.

It must be noted in addition that as in the case of the automatic block on double line track the relay is placed at the beginning of the insulated track, it is short circuited very completely by the locomotive and a current of $2 \times i_{RB\,\text{max.}}$ is needed to restore the relay to the energised position. The practical consequence of this is that $a_{\text{max.}}$ becomes 0.67 ohm instead of 0.22 ohm. These results agreed *in toto* with those found at Gouda-Oudewater: the value calculated for x alone is a little small but this may be due to the value of l chosen being rather high. On the other hand, it is as well to keep l as low as possible if we want to get results by regulating x. If for comparative purposes the same calculations are made for an American 2-ohm relay for which we also take $i_{R_0} = 0.15$ ampere and $i_{RB\,\text{max.}} = 0.044$ ampere, we get for $x = 0$, $d_{\text{min.}} = 1.25$ ohm, a smaller value than for a 4-ohm relay.

The 2-ohm relay is therefore used for very feeble insulation resistances.

For $i_{RB\,\text{max.}}$ and $x = 0$, we get $a_{\text{max.}}$

$= 0.12$ ohm, a smaller value than for a 4-ohm relay; $I_0 = 0.45$ ampere (with $x = 0$) a higher value than with the 4-ohm relay; $I_B = 1.2$ amperes with a complete short circuit.

For the most unfavourable condition of the track at Gouda-Oudewater of 4 ohms, with a 2 ohm relay, we should get $x = 0.42$ ohm and $I_0 = 0.248$ ampere, that is a value higher than with the 4-ohm relay. With a complete short circuit we would have $I_B = 0.65$ ampere and $a_{max.} = 0.225$ ohm.

Seeing that I_0 is greater for the 2-ohm relay than for the 4-ohm relay and that this is the intensity of current used in service, the 4-ohm relay ought to be used for track with an insulation resistance of 4 ohms.

The 9.2-ohm and 16-ohm relays are not considered in the present case because a tension of 0.6 volt is not enough to operate them, and because even with two cells in series a little higher intensity of current is necessary than for the 4-ohm relay with one cell.

[385 .113 (.494) & 621 .33 (.494)]

Swiss railway electrification results, (1)

By Roger T. SMITH, B. Sc., M. Inst. C. E.

Figs. 1 and 2, p. 147.

(The Railway Gazette.)

In delivering his inaugural address as President of the Institute of Transport in the theatre of the Institution of Electrical Engineers on 10 October 1927, Mr. Roger Smith, after referring to the growth of that Institution, took for his main subject the results of the past six years' working of the electrified portion of the Swiss Federal Railways.

Some study of railways across the Atlantic had convinced him that, at least so far as main-line railways were concerned, American conditions were so entirely different from ours that their experience was more interesting than useful. He had, therefore, chosen Switzerland because we were a part of Europe, and European conditions were getting more similar every year. Moreover, Switzerland had now electrified nearly half their lines, including those with the heaviest and densest traffic. The Federal administration, with commendable frankness, published very full results of working, and what was lacking had been furnished to Mr. Smith through the courtesy of the Chief Engineer.

The original programme of 1918 contemplated that by the end of 1928 some 620 miles of route should be electrified. In 1923 it was decided by the State to accelerate this rate of progress and a sum of £ 2 380 000 was allotted to the Federal Railways for this purpose, in order to provide more general employment and more work for the Swiss manufacturers. The 620 miles were completed in 1926.

With the exception of the short section leading to and through the Simplon tunnel, which is still 3-phase, the whole of

(1) Abstract of the presidential address to the Institute of Transport (London) on 10 October 1927.

the electrified track of the Federal Railways is supplied with single-phase current at 15 000 volts 16 2/3 frequency. The power stations, with the exception of the little power station of Massaboden (which has been working since 1915 and supplies the Simplon section), generate single-phase electricity at 15 000 volts and transmit it at 60 000 volts. Exception must be made of a transmission line 140 miles long between Vernayaz power house and Rupperswill, south of, and close to, Brugg, for which the single-phase voltage is 135 000. This voltage is stepped down to 60 000 for radial transmission from a sub-station near Berne and again from the sub-station at Rupperswill.

The Swiss engineers chose the single-phase-system as that most suitable for their country and its electrical manufacturers in 1912, and the use of this system has been completely satisfactory from the railways' point of view.

The total cost of the work, apart from the subvention, which was regarded as a war expenditure, was £27 780 000.

The hydro-electric powers stations are at Ritom, Amsteg, Barbarine and Vernayaz, together with two small existing stations, one supplying the Simplon, and three privately-owned stations for industrial suppl. All these stations are electrically interconnected. It is anticipated that, by the end of 1929, 400 million kilowatt-hours, which can be provided by the four main stations, will be used for a traffic of 6 000 million gross ton-miles.

Electric locomotives.

With the exception of seven locomotives using three-phase current for the Simplon Tunnel, 275 electric locomotives, all using single-phase electric current, worked the traffic on the electrified lines of the Federal Railways at the end of 1926. In addition, there were 25 electric motor coaches, for multiple unit trains. The remaining traffic was hauled by 732 steam locomotives.

The average density of the traffic in Switzerland can roughly be compared with that in this country by the number of locomotives per mile of route. On the Federal Railways the total number of locomotives, steam and electric (inclusive of electric motor-cars), per mile of route of normal gauge running line, was 0.57 at the end of 1926. That is to say, there were 57 locomotives of all sorts per 100 route-miles of running line.

In Great Britain the total number of locomotives, steam and electric (including electric motor-cars and steam rail motor-cars), per mile of route of normal gauge running line, was 1.3 at the end of 1926, that is to say, there were 130 locomotives of all sorts per 100 route-miles of running line, or, 2 1/4 times as many as on the Federal Railways lines.

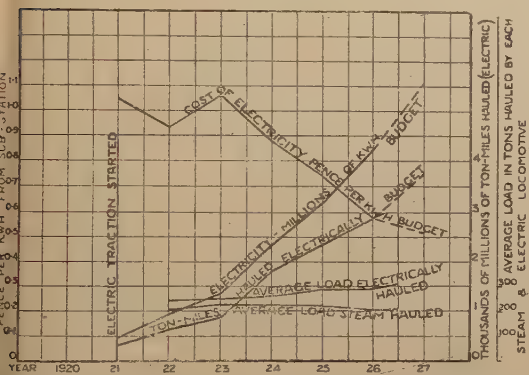
Of the Swiss electric locomotives, the greater number are nominally rated at 2 000 H. P. and designed to haul a passenger load of 470 tons up a gradient of 1 in 100 at a normal speed of 40 miles per hour, exerting a drawbar pull of 22 000 lb. the maximum permissible being 33 000 lb. For hauling trains of 300 tons up gradients of 1 in 38 there is a type of electric locomotive normally rated at 2 000 H. P., which can do this work at a speed of 31 miles per hour up the gradient.

Another type, rated at 2 240 H. P., is used to haul similar passenger trains of 300 tons up a gradient of 1 in 38 at 31 miles per hour. It is also used to haul goods trains weighing 430 tons up the gradient of 1 in 38 at 22 miles per hour and can exert the maximum permissible drawbar pull of 33 000 lb. This type is also used for the heaviest goods traffic hauling a train weighing 1 400 tons up a grade of 1 in 100 at 22 miles per hour.

On the Federal Railways the maximum speed at which any locomotive is designed to run is only 56 miles per hour, while the normal express speed is 44 miles per

hour, and this must be taken into account in dealing later with the speed improvements achieved by electric traction in Switzerland as compared with speeds in this country. The fastest journey in Switzerland is from Geneva, at the extreme west of the lake of that name, to Rorschach, on Lake Constance, at the extreme east, the route passing through the industrial north of the country. The distance between these towns is 240 miles and the average speed, including stops, is 31 miles per hour. This is 19 % quicker than with the displaced steam traction, the journey having been formerly done at an average speed of rather less than 24 1/2 miles per hour, including stops. Switzerland is a mountainous country and the consequent low average speed from the British point of view must be remembered.

The accompanying diagrams show graphically some of the results of working the Swiss railways during the past six years. Mr. Smith commented in detail upon these and other diagrams, illustrating his address, and also compared the working of steam and electric locomotives, showing the superiority of the latter in starting pull and higher average speed. He then examined what the Federal Railways have accomplished in regard to increase of average speed as well as of load.



1. — Cost and amount of electricity for traction delivered from ub-stations to contact wire. Trailing ton-miles hauled elecrically. Average load hauled by steam and by electric locootives.

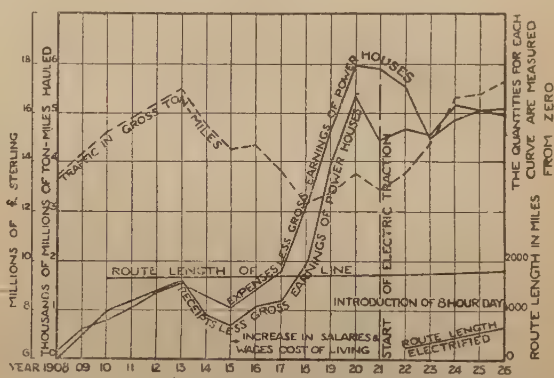


Fig. 2. — Gross traffic hauled (excluding locomotives, including coaches and wagons). Receipts and expenditure less sales of electricity. Total and electrified route length of line.

Figs. 1 and 2. — Graphic statistics of electrification results, Swiss Federal Railways.

Loads and speeds with electric traction on the Federal Railways.

First, as to increased load. On the line from Bâle to Chiasso, the section Erstfeld-Goeschenen, immediately north of the Gothard tunnel (beside which the power house of Amsteg is built), rises in part by remarkable spiral tunnels. The maximum gradient is 1 in 37, and the standard trailing load for goods trains hauled by steam locomotives is 325 tons, and for the similar section south of the Gothard tunnel (beside which the Ritom power station is built), with similar spiral tunnels the steam locomotive load is 320 tons. The electric locomotive load is 490 tons. In 1915 the maximum load in tons of coal which could be transported over the Gothard sections by steam was 11 200 tons daily, and the line was then at the limit of its capacity. This spring, with electric haulage, 21 800 tons were transported in a day.

Then as to increased speed. For the goods-train journey between Chiasso (the Italian frontier) and Bâle (the German frontier) through the Gothard

tunnel, which is a distance of 200 miles, there is a saving in the net running time, *i. e.*, not including stops at stations, of three hours, or 24 %, by the electric haulage of heavier trains.

For the goods-train journey from Geneva to Berne, a distance of 100 miles, the saving in net running time by electric haulage, with a maximum gradient of 1 in 56, is 19 %. For the journey between Brigue, on the Swiss side of the Simplon Tunnel, and Vallorbe, on the French frontier, 120 miles, with a maximum gradient of 1 in 50, the saving in net running time is 19 %.

If for passenger service instead of net running time the actual time of the journey is taken, from end to end, inclusive of stops, the saving in time for express passenger trains between Geneva and Berne, a distance of 107 miles, is 24 1/2 %, and 20 % in the opposite direction. Between Berne and Zurich, a distance of 81 miles, it is 24 1/2 %. The saving in the fastest Swiss journey from Geneva to Rorschach, a distance of 240 miles, already referred to, is two hours all but 10 minutes, or 19 %. For the express international passenger trains from the Italian frontier at Chiasso to Lucerne, 140 miles, the saving is 1 h. 8 m., or 24 %.

From these actual instances it appears that the Federal Railways have found it economical on their steep gradient mountain railways to increase the speed of their fast passenger trains by from 20 to 24 %, and that for their goods trains they work them up to the speed limit with hand brakes of 28 miles per hour, which amounts also to an increase of from 20 to 24 %.

Summary of gains from electrification on the Federal Railways.

1. For an expenditure which will ultimately reach 27 3/4 million pounds on electrification they have, in association with a reduction in the number of employees and a heavy drop in the cost of locomotive coal, succeeded in paying their capital charges on the old and the new capital averaged over the last three years for practically the same traffic as in 1913. Earnings had not fully paid capital charges since 1913, and there are large arrears to make up.

2. They have given an improved fast passenger service with their express trains, decreasing the time of journey by 20 %.

3. They have given a much-improved slow passenger service.

4. They are already hauling much heavier goods trains than steam locomotives could or can haul, the average increase in trailing load being 47 % up to August 1927. They have increased the speed of these heavier goods trains to the maximum permissible without automatic brakes and have doubled the capacity of the Gothard line for carrying minerals.

5. They have, in 1926, reduced the cost of locomotive maintenance per locomotive mile from an average of 5.4 d. per locomotive-mile for steam to 4.4 d. per locomotive-mile for electric service.

6. They have not apparently yet taken full advantage of the intrinsic property of the electric locomotive to work 24 hours per day if needed, and in general to be in service for 80 % of the year, whereas the steam locomotive can only be in service on the average for 40 % of the year. Under favourable conditions about half as many locomotives are needed to run a railway with electric haulage as are needed with steam haulage. This advantage may be secured on the Federal Railways when the 1 000 miles are equipped.

7. Under the special Swiss conditions of lines with many and very long tunnels there is no comparison between the increased comfort of passenger traffic with electric and steam haulage.

8. Electrification has not increased the cost of maintenance of the permanent way; has, together with the fall in the cost of locomotive coal and of wages, reduced the total cost of traction and of workshops and has enabled 34 % more traffic in ton-miles to be hauled by the whole railway equipment — steam and electric — in the last four years, including 1927, without any appreciable increase in the traffic cost of working the trains and the stations.

Mr. Smith then proceeded to make an analysis of conditions on British railways, reproducing two sets of curves from Prof. Dalby's lectures before the Society of Arts, reported in *The Railway Gazette* for 13 May 1927. Referring to British conditions, he asked : Does electrification hold out any hope of helping to relieve the situation? Carefully worked-out estimates for main-line electrification schemes in this country over long lengths of route have shown that the savings in working expenditure as compared with steam will pay on the cost of electrification from 5 % on fairly busy lines to as much as 12 % in lines fully worked with dense mineral and goods traffic throughout the 24 hours.

The capital cost per route-mile of double track for suburban lines amounted to £25 000 per mile of double track. For a route-mile of main line, the corresponding items — track electrical equipment, sub-stations, electric cables, track circuiting and signalling, will cost double this amount, and to this sum has to be added the cost of alterations to existing way and works and signalling which will probably increase the cost to at least £60 000 per mile of double track. Both amounts assume that electricity is bought at or near the sub-stations, but reasonable transmission is included. Both amounts also assume that, since from three-quarters to a half of the number of steam locomotives required to work a given service are required for corresponding electric haulage, all electric locomotives can be purchased from the locomotive renewal fund.

The similar items to the above capital cost for the 1 000 miles of route on the Swiss Railways will, by the end of next year, amount to some £12 000 per mile of route, more than half their total expenditure being on power stations and electric locomotives. The two countries are, however, not really comparable, for the English equipment is for a density of traffic between two and three times as great as the Swiss traffic. The results of Swiss experience would, however, he hoped, stimulate railway officers to look at railway electrification not only from the point of view of saving working expenses but from the point of view of increasing the earning power of a certain investment in way and works through increasing average train speed.

[656 .281. (01)]

Some notes on unexplained derailments, [1]

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Figs. 1 to 8, pp. 154 to 166.

(The Railway Gazette.)

Investigation of the causes of derailment must always be a matter of considerable interest to railway engineers, because, given an adequate standard of track and rolling stock design and maintenance, they should be an impossibility; therefore their occurrence is a direct indication that avoidable defects exist. The class of derailment now to be dealt with is that occurring on open track between stations in which no foreign obstruction played a part, and where the risks entailed by defective operation of points and crossings in and about stations are absent. Tracing the cause of such accidents is not always a simple undertaking, and the obscurity in which it may be shrouded frequently results in no satisfactory final explanation being forthcoming : hence the title selected for these notes. The reason is to be found in the cumulative and synchronising effect of different contributory factors, and when it is remembered that the analysis thereof is often in the hands of departmental representatives whose instinctive first interest is to show that that part of the equipment for which they are responsible was in good order, it is hardly a matter for surprise that the reports reaching the management fail to assign any definite cause, or afford a reasoned theory built up on an impartial consideration of all circumstances, as far as ascertainable.

In countries more developed than those in South America an investigation by some public authority normally provides the desired impartiality, but this in itself indicates a condition of affairs demanding a generally higher standard of railway efficiency, and therefore diminished chances of the class of accident in question. It is financially impossible to maintain the same standard of perfection on a railway carrying, say, one or two trains a day, as on another dealing with a dense and continuous traffic, notwithstanding the fact that the same measure of security can only be reached on the former by the adoption of standards similar to those obtaining on the latter. This is a problem for the management with which we as engineers are not concerned, except in so far that the inevitable result provides risks of derailment, though the opportunities for study may not otherwise be available. Here it is pertinent to remark that the permanent way of a poor and struggling railway offers the most tempting field for the exercise of economies. Ballast, sleepers, and rail renewals always represent large items of expenditure, while the conse-

(1) Lecture delivered to the members of the Institution of Locomotive Engineers (South American Branch).

Classified statement of different types of vehicles, showing the relative sensibility to derailment of goods stock, having regard to the cases recorded and the percentages of each class to the whole stock.

TYPE OF WAGON.	Goods vehicles.									Brake vans.	Carriages.	Engines.	Tenders.
	2-axle open.	2-axle box.	4-axle open.	4-axle open high-capacity.	4-axle box.	4-axle box. high-capacity.	4-axle sheep double-decked.	4-axle cattle.	4-axle cold storage.				
Number of derailments recorded.	12	51	2	4	5	8	5	1	3	1	Nil.	3	2
Percentage of total goods stock	31.6	16.4	10.4	8.9	3.6	0.4	3.5	23.4	2.3	...	...	...	...
Relative sensibility to derailment.	38	314	19	4.5	140	2 000	143	4.27	130	...	...	...	...
Reduced to unity	9	73	4.5	10.5	33	470	33.5	1	30.4	...	...	...	...

quences of delaying such works are not so immediately apparent as would be the case were a similar policy of postponed maintenance applied to rolling-stock. Relatively small defects in engines and vehicles may readily put them out of service altogether, while a good deal of deterioration in track maintenance must accumulate before it reaches a stage at which it becomes unfit to carry traffic.

These remarks may be interpreted as leading up to the conclusion that track conditions are the controlling factor in derailments, and the author, in spite of his association with the mechanical departments and the partiality thereby implied, must confess to the opinion that this is so; but for various reasons rolling-stock contributes factors which have a marked bearing on the issue, and an investigation of these will reveal conditions that merit careful consideration. Further to this, the wider the field of experience and observation derived from actual occurrences of the kind, the better the opportunity for arriving at reliable conclusions as to what constitute the determining influences.

The following is a classified statement of vehicles figuring in derailments coming under the direct observation of the author and covering a period of 20 years.

They have occurred chiefly on curves, with a preference for entry and exit thereto, but cases of derailment on perfectly straight track occasionally take place, thus indicating that operating forces peculiar to curves are not an indispensable factor.

The outstanding characteristic of most, if not all, such derailments is the mounting of the wheel flange, which after running some 3 or 4 m. (10 to 13 feet) diagonally across the rail surface and leaving a mark of its track easily traceable, drops on the outside. On curves this invariably takes place on the outer rail. This evidence enables

the exact point of derailment to be located, and it should be looked for immediately. What happens subsequently is a matter of no moment, as far as our present purpose is concerned, but it merits reference because the spectacular effect of a disastrous smash-up compared with the apparent unimportance of, say, one axle dropping off the track which the driver happens to notice in time, stops, and enrails again in a few minutes, is so marked that it is very easy to overlook the fact that both occurrences are essentially of equal importance as to origin, and merit the same thorough investigation. Subsequent effects of derailments depend almost wholly on the holding power of the draw gear. If it resists, the derailed vehicle (generally one axle) may run for miles, especially at night time, without attracting attention. If it fails the vehicle will get across the track, and form a nasty barricade on which the following portion of the train may pile up.

This kind of derailment is due to one immediate cause and one only, *viz.*, a temporary disturbance of load distribution over the wheels of the vehicle resulting in the wheel which mounts the rail being relieved to a great extent of the load it should normally carry. This may seem a mere platitude, put in this form, but spontaneous recognition of the fact is quite another matter, and it is rarely used as the foundation stone on which to build up subsequent investigations and deductions. Obviously recognition of the fact directs the course of investigation in the right channel, for the problem awaiting solution is circumscribed within the question, what caused the disturbance of load distribution ? Here we are faced with a variety of causes and effects, and it is the contributory character of most of them which often renders it difficult to attribute the accident to any particular one. On the other hand, the absence of some particular influence may very well have saved the occurrence, from which is to be deduced the supreme importance of eliminating in designs, wherever possible, any features likely to prejudice, directly or indirectly, the question of load distribution.

Before proceeding to consider various influences which may be contributory causes of defective load distribution, the author, for the sake of clearness, offers the following definition of what may constitue such, to wit : Each must possess the inherent capacity, when sufficiently magnified, to produce unaided the effect contemplated. Coming within this definition are the following :

a) Track irregularities.

b) Super-elevation developed on tangents.

c) Oscillations and lurching.

d) Actual faulty distribution of load carried.

e) Defective springing and want of flexibility in rolling-stock.

The omission from this list of « speed » may provoke comment, and it will therefore be dealt with at once. Briefly, it is not included because it will not come within the definition quoted. Assuming track and rolling-stock to be in satisfactory condition, the author submits that derailments of the kind dealt with are a physical impossibility as a result of speed. The effect of speed is chiefly apparent on curves where the guiding tendency set up presses the wheel flanges against the outer rail, and a corresponding tendency to climb follows. This is counteracted by the greater weight imposed on the wheel at the same time by centrifugal force. With the centre of gravity of the vehicle located at a height above rail level not less than half the track gauge, the increase in weight thrown on the outer rail is equal to the

increasing horizontal thrust, and remains so as the speed increases. Since in normal types of rolling-stock the centre of gravity is always higher, it will be found by resolving the centrifugal force generated into its horizontal and vertical components that the major effect is in favour of holding the wheel down. Every day experience demonstrates that trains run with safety at high speed on sharp curves, and that the vertical component of the centrifugal force suffices to counteract the outward thrust, and any climbing tendency due to angularity of the surfaces in contact between wheel flange and railhead.

At excessively high speeds a condition is reached when the effect of centrifugal force will overbalance the weight of the vehicle and it will heel over, the wheel running on the outer rail pivoting on the latter until the position of the flange is so altered that it is no longer able to function as a guide. Such occurrences are exceedingly rare, and are not derailments within the strict meaning of the term. The fact that they are possible, however, substantiates the contention that speed, no matter how far magnified, is incapable of producing a true derailment, because it is an established fact that heeling over will occur first. The circumstance is nevertheless so little recognised that the question of speed is always given an unmerited prominence in cases of derailment.

By way of illustrating the point, the extreme case may be taken of a driver failing to observe a precaution order in passing over a known defective piece of track, and a derailment ensues. The excessive speed is immediately given as the cause of the accident, whereas reflection will show that in reality it was the defective condition of the track. Speed may thus be an associated factor, but never a contributory cause in derailments.

Track irregularities.

These may be defined as defects of alignment of rail surface in both horizontal and vertical planes, but the latter are those chiefly responsible for disturbance of load distribution. They originate as a result of uneven support of the sleepers and dropped rail joints, and when associated with high centres of gravity and speed may set up oscillations and lurchings which inevitably have a most marked effect in disturbing load distribution. Regarding rail joints, the author's experience has been with track laid with parallel joints as distinguished from staggered ones. The former represents English practice, and tends rather to produce pitching, while the staggered joint would promote rolling, and more directly affect load distribution. The latter is common practice in the United States, and with well-sprung vehicles produces the sensation of smoother travelling, since the intensity of the blow is diminished, as well as the noise. However, as far as the present issue is concerned, the parallel joint is to be preferred.

As mentioned previously, there is generally little difficulty in locating the exact spot where the wheel flange climbs the rail, and any damage suffered by the track will be in advance of this point in the direction of running. This circumstance is fortunate in so far that track defects causing, or contributing to, the derailment will remain unaffected, and may be fully investigated since their occurrence is antecedent to the critical spot. Apart from any immediately obvious irregularities, the precaution should be taken of running some heavy vehicle slowly over the track for a short distance preceding the point of derailment, as this will reveal slack places under the sleepers if such exist. On curves such slack places may be equally

prejudicial whether occurring on the outer or inner rail.

Super-elevation.

The primary object of elevating the outer rail of a curve relatively to the inner one is to compensate the disturbance of load conditions brought about by the action of centrifugal force. Since this force varies with every variation in speed, it is obvious that, whatever the super-elevation selected, it can only be right for one particular speed. This shortcoming is more noticeable on single lines of railway involving considerable curvature and grading, as in such circumstances inevitable extremes of speed will be encountered on the same curve. Now, when dealing with speed as a factor in derailments it was shown that, from the point of view of holding the wheel down against the climbing tendency due to curvature, the effect of centrifugal force was beneficial, from which it is apparent that if the super-elevation is excessive for any given speed this effect is not only nullified, but a definite load disturbance results whereby excessive weight is thrown on the inner rail where least needed. The author has felt justified in specific instances of derailments of vehicles with high centres of gravity at slow speed of indicating this effect as a possible contributory cause, and suggesting that at higher speeds the accident might not have occurred.

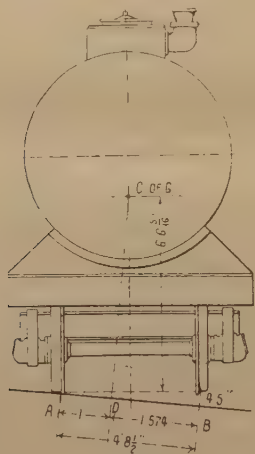

Fig. 1.

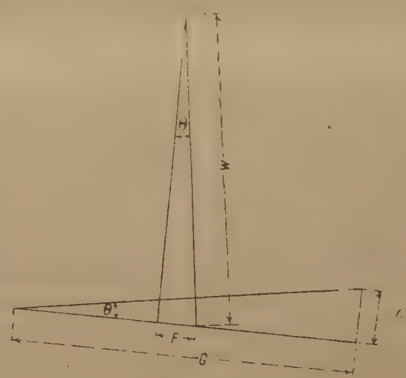

Fig. 2.

The extent to which super-elevation directly affects load distribution is shown in the diagram, figure 1. The vehicle is an oil tank wagon, the common centre of gravity of which in fully loaded condition is shown to be 6 ft. 6 5/16 in. above rail level. It is shown standing on track with a super-elevation of 4 1/2 inches and curvature of, say, 18 chains. Practice in regard to amount of super-elevation varies appreciably, depending on local conditions, and the figures quoted are taken as representing what may frequently be encountered.

In the circumstances the total weight of 50.4 tons, instead of being equally divided between the two rails is altered, the higher rail being relieved of 5.62 tons which is added to the normal weight

carried by the lower one. This state as at rest would involve a speed of 37.8 miles per hour in order that the resulting centrifugal force on the curve selected may compensate the initial load disturbance.

Thus it is obvious that, at speeds less than those sufficient to establish a balance, super-elevation is a direct cause of disturbance of load distribution, tending to relieve the wheels running on the outer rail of their share of the total weight. At higher speeds centrifugal force becomes the disturbing factor in the opposite direction, but it may be noted that even in the case of such a vehicle as the loaded tank car, with its relatively high centre of gravity, it would require a speed of 88.55 miles per hour to effect heeling over on the curve described. Such a final result could be counteracted by increasing the super-elevation, but the outcome would be dangerous instability at low speeds, so that in practice the best compromise has to be selected to meet the extremes of speed likely to be encountered, and the greater the range of these the less satisfactory the compromise will be.

It may here be noted that variations in the height of the centre of gravity do not materially affect the speed required to establish a balance of load, as will be noted by comparing the vehicle considered with another of similar total weight with an assumed centre of gravity 4 feet above rail level given in the appendix. On the other hand, the speed required to overturn the latter is found to be higher, *viz.*, 109 miles per hour on the 18-chain curve.

Thus it appears that super-elevation at the best can only be a compromise, and where extremes of speed prevail it is preferable that it should err on the low side, for at moderate speeds it directly produces undesirable disturbance of load distribution, while there exists a wide margin of safety over and above any high speeds met with in practice to ensure adequate stability against overturning.

It is still a common practice to develop super-elevation on the tangents leading up to curves. The result is that a definite disturbance of loading follows in the absence of any compensating centrifugal force, and the vehicle finally strikes the curve in a condition the reverse from that desirable, *viz.*, with those wheels subject to a climbing tendency already relieved of a portion of the weight they should normally carry. This defect can be met by the use of transition or spiral curves when the gradual rise of the outer rail will bear a proper relationship to the curvature, and where this is not done an avoidable contributory cause of derailments is incurred.

There is another point worth notice in connection with development of super-elevation. No matter how gradual, it sets up a tendency to transfer loads to diagonally opposite bearings, and is therefore a positive agent in producing defective load distribution. Its counterpart in a two-axle vehicle would be unequal spring camber, or cross wind in the body structure. In practice, flexibility of springs and a sufficiently long run-out combine to counteract the effect; but there is always the danger of local variations in the rate of development provoking an undue disturbance of loading, so that in case of derailment occurring in the vicinity of developed super-elevation possibilities of irregularities in the rate should be investigated.

The author recently had to deal with a case of unexplained derailment of a two-axle box wagon in a siding. The incident was duly investigated by representatives of the Traffic, Locomotive, and Way & Works Departments, and in their joint report the cause was left unexplained because it was stated that no defect of any sort could be discovered in either the wagon, its method of load-

ing (which was very light), or the track. Incidentally, however, they at the same time unwittingly recorded the cause by mentioning that 4 inches of super-elevation was developed in a length of some 20 m. (22 yards). The rate was very excessive, involving a difference of level of 1/2 inch in the wheelbase of the wagon, which in consequence was travelling on three wheels instead of four. When this was subsequently pointed out, the author was met with the argument that, admitting the excessive rate of development of the super-elevation, other causes must have operated as well since numberless vehicles had passed the spot in safety.

This line of reasoning is very common and worthless. It takes other forms — for instance, it is testimony to the satisfactory condition of the vehicle that having run some distance before derailment there can have been little wrong with it, or, again, there being a large number of vehicles in the train all of which, with the exception of that which derailed, passed the spot in safety (?), the latter must have been the culprit. Both arguments are equally fallacious, because they fail to take cognizance of the undoubted many narrow escapes from derailment. In other words, the factor of safety is dangerously reduced, and immunity from disaster dependent on odd chances. The investigator should therefore carefully eschew this line of reasoning, however tempting it may appear.

Oscillations and lurchings.

The origin of these undesirable movements is track irregularities, but their amplitude depends upon speed and factors in rolling-stock design such as width of the vehicles and height of centre of gravity, which will be dealt with further on. As far as the track is concerned their elimination is purely a question of maintenance, and without doubt they constitute one of the most potent contributory causes, and frequently the direct one. The author offers no further comments on this aspect of the subject, because the question is one of finance and not engineering.

Faulty load distribution.

In goods stock the load carried may constitute a weight greatly in excess of the vehicle itself, but whether this is the case or not, as when a partial load only is carried, its careful distribution is a matter that should always receive the closest attention, and it is here that the traffic department can co-operate in the avoidance of deraitments, or by negligence contribute very acutely towards them. The matter assumes greater importance where the character of the traffic involves relatively small consignments for different stations loaded in the same vehicle, because as these are unloaded the original distribution of weight may be prejudiced unless a rearrangement of the remaining load is effected before the vehicle proceeds on the next stage of its journey. Two-axle stock demands the greater attention on this score because the overhang at the ends beyond the axles is relatively greater than with bogie vehicles, so that concentration of load behind the trailing axle may well relieve the leading one of weight to a dangerous extent.

The latter circumstance, and the possibilities involved, determine the allowable width of vehicle. This point will be dealt with more fully under the head of rolling-stock design, but many instances of its effect have come under the author's observation in connection with wide bogie stock. Although these occurring for the most part in stations do not for this reason come within the scope of the class of derailment under review, they nevertheless vividly illustrate the effect of unequal load distribution. Such wagons with an overall width of 9 ft. 10 in. on a 4 ft. 8 1/2 in.-gauge loaded

with sand stone, coal, etc., are very sensitive to derailment when, for convenience, half the load may be discharged from one side, and the wagon then be shunted to some other point to discharge the remainder. In such circumstances, if curves are encountered, the possibility of derailment is imminent and very frequently occurs.

Movable loads such as liquids and livestock may constitute an uncontrollable source of defective distribution, and consequently a greater restriction of width is desirable in stock specially provided for this class of freight.

It will be gathered from the foregoing that distribution of load carried by a vehicle calls for investigation when derailment occurs, but in this connection it is an unfortunate circumstance that jolting or possible overturning resulting from the accident may be so disturbing a factor that the original condition of the load is not ascertainable. Nevertheless, the point should receive attention, and where the evidence of the vehicle itself is unreliable any obtainable information from traffic employees should not be overlooked.

The accompanying record shows that carriages, brake vans, and engines are least subject to derailment, and of these it may be noted that in no instance has a carriage derailed in the period of 20 years covered. The reason for this is that the weight of these vehicles is constant, or varies within much narrower limits than goods stock, thus enabling greater flexibility of springing. The extent to which this flexibility can be carried is purely a question of constancy of load, and the author's experience is that where this condition is secured even two-axle stock can be made practically immune from derailment. During the period covered by the records quoted, and earlier, numbers of two-axle carriages carried on long and flexible laminated springs were in service without a derailment ever being recorded, while at present such vehicles, used only for service purposes, apparently enjoy complete immunity in spite of an overall width of 10 feet on standard gauge. In the same manner greater spring flexibility in bogie carriage stock is an important factor in securing adaptability to track irregularities, though considered as a vehicle the bogie enjoys in itself a measure of adaptability due to the concentration of load carried at a central point which normally secures an even and constant distribution.

It is not proposed therefore to consider further the very few derailments recorded in the case of engines and carriages, since the purpose in view is served if it is realised that the immunity enjoyed is attributable to the causes referred to.

Turning to goods stock, it will be noticed that an attempt has been made to arrive at the relative sensibility to derailment of different classes of stock by multiplying the number of derailments by 100 and dividing the product by the percentage of any given class to the whole stock. The method, of course, assumes relative constancy in the numbers throughout the period dealt with and equivalent volume of running, but since variations will have occurred the result can only be considered an approximate indication. It nevertheless agrees fairly well with impressions gathered from experience. The types of vehicles figuring are illustrated in figure 3, which gives a cross-sectional view only, since the length of them does not appear to materially affect the issue.

It will be seen at a glance that the wagons most subject to derailment are those of the box type, both two and four axles, and double-deck sheep wagons. The fact points to a high centre of gravity having a marked influence because the containing sides of a box wagon facilitate the piling up of relatively

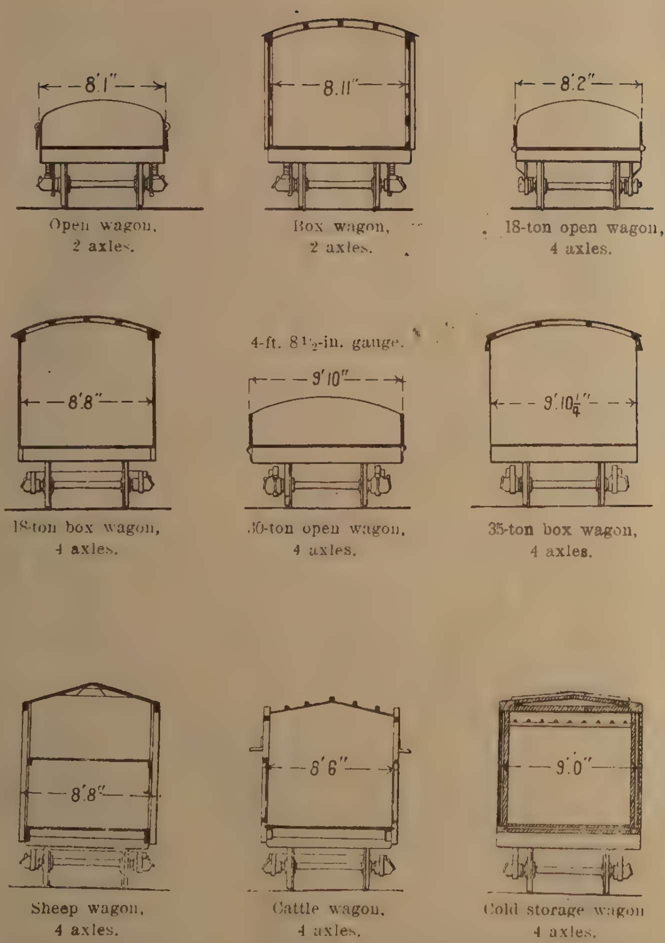
8'1"
Open wagon, 2 axles.
8'11"
Box wagon, 2 axles.
8'2"
18-ton open wagon, 4 axles.
8'8"
18-ton box wagon, 4 axles.
4-ft. 8½-in. gauge.
9'10"
30-ton open wagon, 4 axles.
9'10¼"
35-ton box wagon, 4 axles.
8'8"
Sheep wagon, 4 axles.
8'6"
Cattle wagon, 4 axles.
9'0"
Cold storage wagon 4 axles.

Fig. 3.

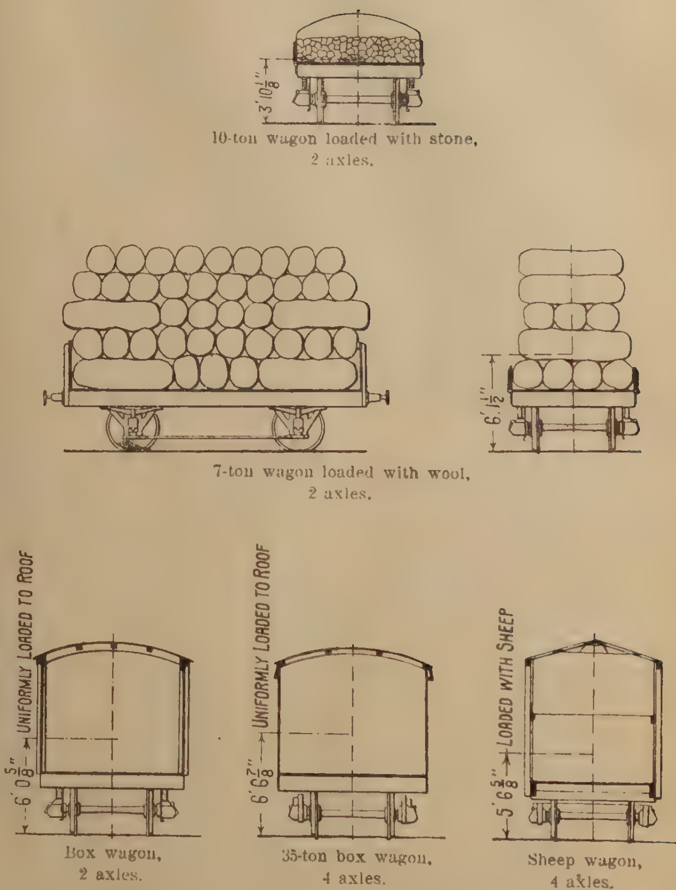
3'10⅛"
10-ton wagon loaded with stone, 2 axles.
6'1½"
7-ton wagon loaded with wool, 2 axles.
UNIFORMLY LOADED TO ROOF
6'0⅝"
Box wagon, 2 axles.
UNIFORMLY LOADED TO ROOF
6'6⅞"
35-ton box wagon, 4 axles.
LOADED WITH SHEEP
5'6⅝"
Sheep wagon, 4 axles.

Fig. 4.

heavy loads to the roof. The corresponding position of the centre of gravity under such conditions is shown in figure 4, and compared with that of a two-axle open wagon loaded respectively with stone and wool. It will be noted that notwithstanding the apparently top-heavy appearance of the wagon loaded with wool, the common centre of gravity is not higher than in fully loaded box wagons, while the nature of the loads in the former ensures an even load distribution.

In this connection, special mention is called for in the case of the four-axle wagons of high capacity which, it will be noted, are of exceptional width (9 ft. 10 1/4 in.), as it is evident that this feature, combined with a possible high centre of gravity, has rendered them far more sensitive to derailment than any other class of stock represented. In practice this tendency had to be met by strictly limiting the height to which loads could be piled, and the type has not been perpetuated.

Reference may also be made to the cold-storage wagons in which the load of chilled carcasses is suspended from the roof by hooks. The three derailments recorded were undoubtedly due to defects in the track, but they directed attention to this particular method of loading and the effects it might produce by raising the centre of gravity. It is therefore as well to remember that the centre of gravity depends on location of mass and not on the method of support, and in the case in point would only be affected by the extent to which the load is lifted above the floor, in practice a matter of perhaps 6 inches. Apart from this the vehicle would have no higher centre of gravity than any other box-type loaded from floor to roof. The real risk involved in this method of loading is derived from possibilities of the carcasses swinging in response to oscillations of the vehicle, and the matter was closely investigated at the time. It was found, however, that they were packed so tightly as to constitute an immovable mass in the wagon, this condition being retained on arrival at destination after a journey of 350 miles. With this condition fulfilled, and the overall width of 9 feet as shown not exceeded, this type of vehicle should offer no special tendency to derailment.

It will be noted that, judged by the method adopted, the four-axle cattle wagon shows the greatest immunity from derailment, not only relatively but in actual number of cases recorded, and has, therefore, been taken as representing unity. The author attributes this to the relatively low centre of gravity, and still narrower width, *viz.*, 8 ft. 6 in., notwithstanding the possibilities of load fluctuation inseparable from the live character of the cargo. The type of bogie used is also free from objections common to that of the diamond frame pattern, which will now be considered.

This type of bogie, as illustrated in figure 5, is probably more extensively used for goods stock all over the world than any other. The design shown in all essential particulars is a common one in South America, and the author believes owes its origin to the pioneer days of North American railways. As in the case of locomotive frames, bar iron was used because it was more easily procurable, and what was originally an adaptation of design to suit available material has since been perpetuated as a matter of custom. It embodies the objectionable feature of axle-boxes bolted rigidly to the side frames, and a want of flexibility hindering ready response to track irregularities. If the bolster and springs are removed it will be seen that what remains is a more or less rigid spring bed fixed to the two side frames. Relative movement of the latter in a vertical plane is, therefore, only possible by actual torsion of the spring bed, hence with

axle-boxes bolted into the frames a positive opposition is set up. In the early days, when this spring bed was a plank of wood, the matter was perhaps not of much importance, but to-day it generally consists of a heavy steel section, and the rigidity imparted is definite and lasting. This bogie thus exposed constitutes in itself a four-wheeled vehicle devoid of means for adaptation to irregularities of the surface passed over, and its counterpart could be had by discarding the springs of an ordinary two-axle wagon and bolting the axle-boxes rigidly to the horn stays. The bogie would have the advantage of a shorter wheelbase, the defect in practice being one of degree. It is, of course, a fact that many thousands of vehicles so equipped run year in and out with more or less immunity from derailment. This, nevertheless, loses its validity as an argument if it is borne in mind that the accidents under consideration are due to the synchronisation of contributory causes, and that the elimination of one may render the effect of the remainder innocuous. An object lesson in this issue has come under the author's observation in a model garden railway where the diamond frame bogie was reproduced in the form of two cast-iron side frames pivoted in the centre to the bolster. The pivot consisted of a screw, and it was only necessary to tighten these sufficiently to make the connection more or less rigid to produce derailments at will. The method is a very effective means of overcoming the objectionable inflexibility referred to, but in practice the carrying of heavy loads on a pivot would probably not prove sucessful.

The foregoing considerations point to the desirability of discarding this design of bogie frame, and adopting in its place a substitute embodying the essential feature of an axle-box guided between horn stays and directly spring-borne. Bar iron, if preferred, may still be used for the frame of the bogie, and is embodied in the design shown in figure 6, which is one recently adopted by the author. It includes a swing bolster, a feature of undoubted value in absorbing lateral shocks, and in the form shown adds little to the cost of the bogie.

It seems strange that what appears to have been deemed an essential feature in the earliest type of railway rolling-stock, *viz.*, free play for the axle-box as a means of meeting the track irregularities of pioneer railways, should to-day be so largely ignored in the class of stock referred to. Track standards have doubtless improved greatly, but not to an extent justifying rolling-stock designers assuming that adaptability to possible irregularities can be dispensed with.

Reference has been made to the immunity from derailment which may be attained in two-axle passenger stock under conditions of constant loading. It is the opposite of this condition in goods stock which renders it difficult to attain the same measure of security. The ordinary two-axle wagon of 10 tons capacity will weigh from 5 to 6 tons, of which 1 1/2 tons may represent the wheels and axles. The springs are therefore called upon to bear weights varying between 3 1/2 tons and 13 1/2 tons, under which conditions it appears impossible to attain desirable flexibility. Where traffic requirements demand the use of this type of wagon, immunity from derailment can only be secured by a high standard of track and stock maintenance, and the exercise of constant care in equal distribution of the load carried. The author would here refer to a method adopted by the Central Argentine Railway for overcoming the excessive spring rigidity of two-axle stock in the empty or partially loaded condition which is said to have given satisfactory results. This is shown in figure 7, and as will be seen, embodies the use of an auxiliary leaf spring inverted over the main spring. Its unloaded form is shown in full lines, but loaded it

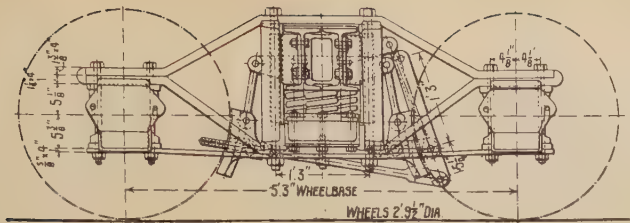

Fig. 5.

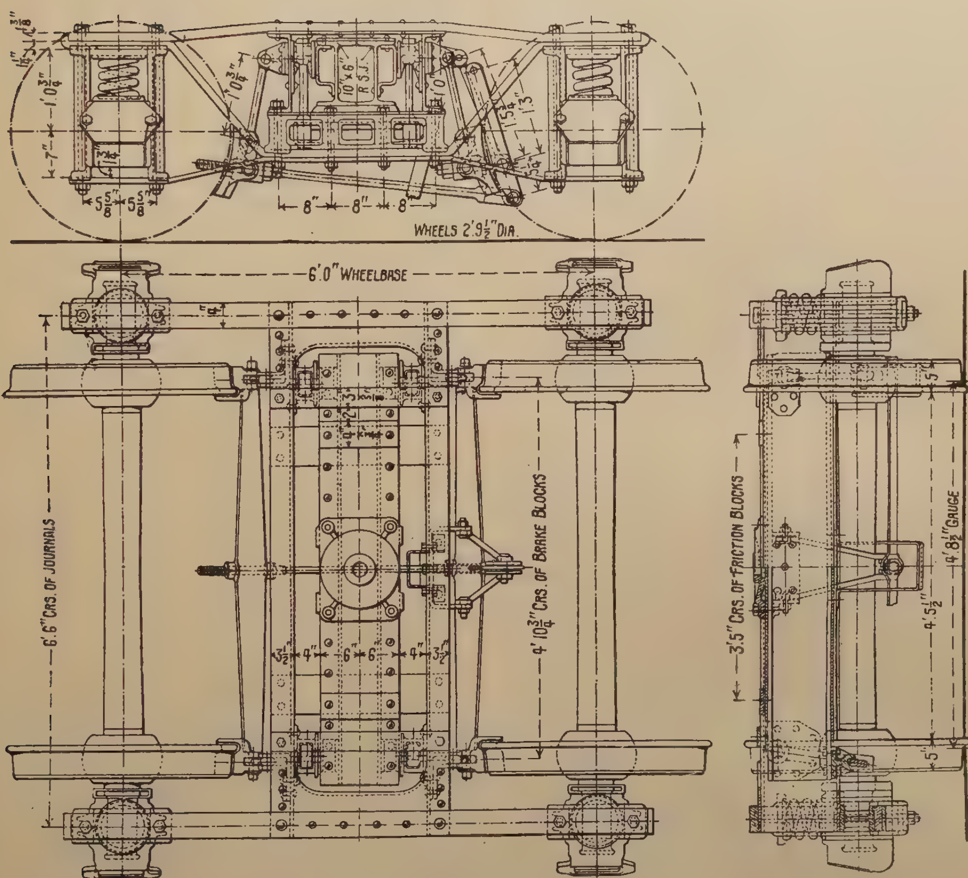

Fig. 6.

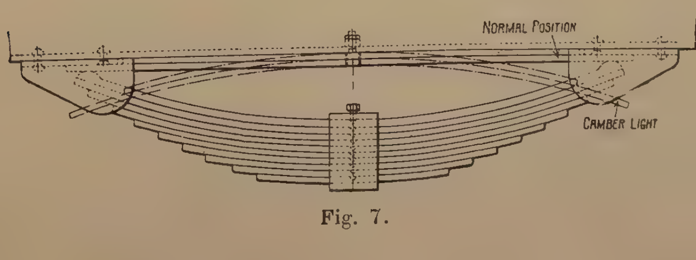

Fig. 7.

is quite flat under the sole bar, the idea being that the increased measure of elasticity afforded would ensure a sufficient pressure being maintained on the axle-box under extreme conditions of track irregularities.

Defects in rolling-stock.

These, as contributing to faulty load distribution and consequent derailment, are not so easily investigated as those of the permanent way, because after the event it is often difficult to distinguish between defects which may have pre-existed and those resulting from the derailment. In fact, almost any defect capable of contributing to a derailment may also be a result of it. The best course open for those responsible is to pay special attention to the following simple matters on the ground that prevention is better than cure.

Two-axle stock.

There should be constant observation that spring camber is equal and that axle-box brasses have not an excessive amount of side play.

Four-axle stock.

Bogie friction plates should not touch on both sides together, since such action tends to hinder freedom of swivelling on curves. Cross wind in the bodies of bogie stock, causing contact at the same time between diagonally opposite friction plates of the bogies, is to be avoided. A perfectly level and permanently solid piece of track in the repair shops is essential to ensure this being effectively tested.

This may not appear a very formidable list of possible defects in rolling-stock, but when it is remembered that the derailments under review are invariably the result of disturbed load distribution, it will be seen that those responsible for rolling-stock maintenance can best contribute to immunity by seeing that vehicles stand plumb and square both empty and under conditions of uniform loading.

Dimensional restrictions in rolling-stock design.

The author is not aware that anything in the shape of limitations in the overall dimensions of vehicles in relation to the gauge of track has ever been attempted in the interests of securing stability. Probably conditions affecting the issue are too variable to allow of any hard-and-fast recommendations being made. Nevertheless, the wide discrepancies to be met with in this relationship as between practice on narrow and broad-gauge lines point to the conclusion that the former tolerate widths which are undesirable, or the latter fail to take full advantage of the possibilities offered by the gauge. The following are examples of the width of vehicles to be met with on the metre, standard, and Argentine broad-gauge (5-ft. 6-in.) lines :

	Overall width.	Ratio of width to gauge.
Metre (3 ft. 3 3/8 in.)	8 ft. 10 in.	2.7 to 1
Standard	10 feet.	2.12 to 1
Broad gauge	10 ft. 6 in.	1.91 to 1

The widths quoted correspond to passenger stock, and, as already seen, as far as the standard 4-ft. 8 1/2-in. gauge is concerned, experience has demonstrated that the width is one which can be adopted without risk of derailment.

This ratio, however, is much exceeded on the metre gauge, and the latter applied to the broad gauge would provide a vehicle with an overall width of 14 ft. 10 in. It would prove interesting if those members associated with metre-gauge lines could afford any data tending to show how far such ratios can be adopted with immunity from derailment and comfort in travelling.

The low centre of gravity, uniform load distribution, and flexibility of

springing all favour stability, but where indifferent track conditions and considerable curvature are met with a tendency to rolling will develop, which often becomes unpleasant for passengers. Again, the addition of a few extra inches of width in carriages is of no advantage unless they secure the minimum width required for an extra seat. The overall width quoted above for standard gauge allows sufficient interior width for two passengers on either side of an ample central passageway even in dining cars, but to seat another with equal comfort 18 inches would have to be added. This could be done on the 5-ft. 6-in. gauge without exceeding the ratio quoted for the 4-ft. 8 1/2-in., but, as far as the author is aware, the fact has not been taken advantage of by Argentine railways. It may be noted that if 9 feet is the allowable width of stock on English railways, the ratio to gauge is the same as that for the Argentine broad-gauge lines, and doubtless fixed structures constitute the limiting factor in both instances. It cannot be foreseen whether in the future the restriction will be so deplored here as it is to-day in England, but, in any case, it has compensations in the extra stability secured and comfort of travel enjoyed, and, considered in conjunction with other natural features, affords potentialities which only depend upon well-designed and maintained road beds to make railway travelling in the Argentine the fastest and most comfortable in the world. Sir Seymour B. Tritton, President of our Institute, referred to the matter of loading gauges in his presidential address, and from the data given it appears the broad-gauge Indian railways (5-ft. 6-in.) are considering a limit of breadth of 12 feet, involving a ratio of 1 to 2.18.

It would appear from the foregoing that the greatest width in relation to gauge is attained on the metre and other narrow-gauge railways, but it is not apparent that any circumstances exist rendering this possible without prejudice to stability, and the author concludes that the ratios quoted above for the standard gauge allow of overall widths beyond which it is not desirable to go.

Turning to goods stock, the question becomes more complicated, and the restrictions under consideration are influenced by the varying position of the centre of gravity, unequal load distribution, and want of flexibility in springing.

Based upon the considerations embodied in these notes and general experience, the author recommends the following restrictions of overall body widths for goods stock of different types expressed as ratios of the gauge :

Box wagons	1.91 = 9 feet.	on standard gauge.
Open flat wagons .	1.96 = 9 ft. 3 in.	
Livestock wagons .	1.80 = 8 ft. 6 in.	

The other important restriction would be the allowable height of the centre of gravity of the loaded vehicle. It is this, in conjunction with track irregularities, which promotes rolling and consequent disturbance of load distribution. Moreover, where considerable curvature is met with the impossibility of adjusting the super-elevation to the ever-variable conditions renders inevitable inequalities of load distribution, and such can only be met by keeping the centre of gravity within limits which it must be conceded could under more favourable conditions be exceeded with all reasonable safety. The author would place this limit at 1.274 times the gauge — or, say, 6 feet above rail level on standard gauge.

Instances where the imposition of such a limit would prove inconvenient are easily found, an example being the cold-storage wagons referred to earlier in these notes. The overall height of these is dictated by the length of the slung carcasses, and special thickness required in floor and roof for insulation purposes, bringing the overall height of

the vehicle up to 12 ft. 9 1/2 in. Loaded under these circumstances, the common centre of gravity is about 6 ft. 6 1/2 in. above rail level, but it may be noted the full load of meat does not represent the full-weight capacity of the wagon, falling short of this to the extent of 6 or 7 tons. Thus, could the wagon be loaded to its maximum carrying capacity with load occupying all the available capacity, the centre of gravity would be raised to 6 ft. 7 1/2 in. These conditions can only be controlled by special instructions, and a relatively high standard of track maintenance.

Another instance worth noting is the oil tank wagon illustrated. This is essentially a narrow vehicle, but its centre of gravity when fully loaded is 6 ft. 6 5/16 in. above rail level. The design is open to criticism on this score, because with a little scheming the tank body could be lowered a few inches. However, to effect any material lowering of the centre of gravity, and retain the same capacity, the shape of tank would need modification, the cylindrical form being flattened to an oval section, or better still, substituted by one of rectangular form. The latter would probably involve increased constructional costs, but the alternative might be worth while in the interests of stability under running conditions.

The author trusts that these somewhat rambling notes on a subject which must at times be a source of anxiety to every railway engineer will be found to contain some indications as to the origin of the class of derailment dealt with which may serve to indicate the measures necessary to prevent their occurrence. From the mechanical side, it seems doubtful whether when designing vehicles due regard is paid to considerations of stability under the conditions to be met in service. By keeping centres of gravity within limits, critical overturning speeds on curves would be higher, thus allowing a wider margin of safety with super-elevations reduced to a point where objectionable disturbance of load distribution at relatively low speeds would otherwise occur.

Restrictions of width of vehicles in relation to gauge merit consideration.

The defects of the diamond frame bogie should be corrected, and the rigid attachment of axle-boxes to the frame be accepted as a cardinal error in design.

The author would again lay stress on the value of a swing bolster in high-capacity goods stock, especially where high speeds may be involved. The absorption of lateral shocks by this means goes far to check the development of dangerous oscillations. It should be remembered that where flexibility of springing is limited for reasons already dealt with, the shortcoming should be compensated as far as possible by adaptability of the bogie itself to track irregularities.

Regarding the permanent way, super-elevation should not be tolerated unless accompanied by a corresponding curvature; in other words, transition curves should be an indispensable feature of track design. The alignment of the rails is, of course, purely a question of maintenance and expense, and if neglected may invalidate all measures taken by the department responsible for vehicle design.

Uniformity in the rate of development of super-elevation is of superlative importance, and the rate itself should be such that it will not appreciably affect load distribution in the longest rigid wheelbase to be carried.

APPENDIX.

Particulars are given herewith of the method employed for arriving at the numerical results recorded in the text.

1. To ascertain centrifugal force set up the formula used is :

$$F = \frac{Wv^2}{gr}.$$

Where W = load,
v = velocity in feet per second,
g = 32.2,
r = radius of curve in feet.

From this is derived the formula used in problem 2, thus (see fig 2).

The centrifugal force and weight of the vehicle are represented respectively by sides F and W of the above triangle and $\sin \theta = \frac{F}{W}$.

Super-elevation $S = G \sin \theta$,
where G = gauge of track.

$$\text{Hence } S = \frac{G \times F}{W} = \frac{GWv^2}{Wgr} = \frac{Gv^2}{gr}.$$

2. To ascertain what speed on a curve of given radius is required to re-establish an equal distribution of load under the condition shown in figure 1, assuming a radius of 18 chains = 1 188 feet, the formula used is :

$$S = \frac{Gv^2}{gr},$$

where S = super-elevation,
G = gauge of track,
v = speed in feet per second,
g = 32.2,
r = radius of curve.

$$\text{Hence } v = \sqrt{\frac{Sgr}{G}}$$

$$= \sqrt{\frac{4.5 \cdot 32.2 \times 1\,188}{56.5}} = 55.2 \text{ feet per second.}$$

(This is equivalent to 37.6 miles per hour, or 60.5 km., and is a theoretically correct speed for load balance under given conditions of super-elevation and curve).

With reference to figure 1.

3. To ascertain load distribution under the conditions shown with vehicle at rest. It will be inversely proportional to AD and DB. Taking the former as unity, DB becomes 1.574. The gross weight of the vehicle is 50 4 tons. Then if X = load at point A,

$$50.4 - X = \text{load at B} ;$$
$$X \times 1 = (50.4 - X) \times 1.574 ;$$
$$X = \frac{79.33}{2.574} = 30.82 \text{ tons.}$$

Load at B = 50.4 — 30.82 = 19.58 tons;

Difference : 11.24 tons

and 5.62 = load to be relieved from the inner rail to cause a balance of the load; then centrifugal force × 78.3125 = 5.62 × 56.5.

Centrifugal force required = 4.054 tons.

Now centrifugal force $= \frac{Wv^2}{gr}$,

where W = weight of vehicle in tons,
v = velocity in feet per second,
r = radius of curve in feet,
g = constant due to gravity = 32.2.

$$v = \sqrt{\frac{C \times g \times r}{W}}$$

$$= \sqrt{\frac{4.054 \times 32.2 \times 1\,188}{50.4}}$$

$$= \sqrt{3\,076.98}.$$

= 55.47 feet per second.
= 37.8 miles per hour.
= 60.83 km. per hour.

4 To ascertain speed required to effect heeling over. This is a function of the centrifugal force acting at the centre of gravity of the vehicle balancing the weight acting through D, figure 1, and taking the conditions as shown the moment about B must be equal, thus :

Centrifugal force (F) × 78.3125 = W × DB.

Hence $F = \frac{50.4 \times 34.55}{78.3125} = 22.24$ tons.

Hence the speed v necessary to set up the force F is found to be :

$$v = \sqrt{\frac{F \times g \times r}{W}}$$

$$= \sqrt{\frac{22.24 \times 32.2 \times 1188}{50.4}} =$$

129 9 feet per second.

This is equivalent to 88 55 miles or 142.5 km. per hour.

5. Same as Nos. 3 and 4, with assumed centre of gravity 4 feet above rail level, giving following result — other conditions equal :

Speed necessary to establish equal distribution of load . . 37.95 miles per hour.
Speed necessary to produce heeling over . . . . 109.0 miles per hour.

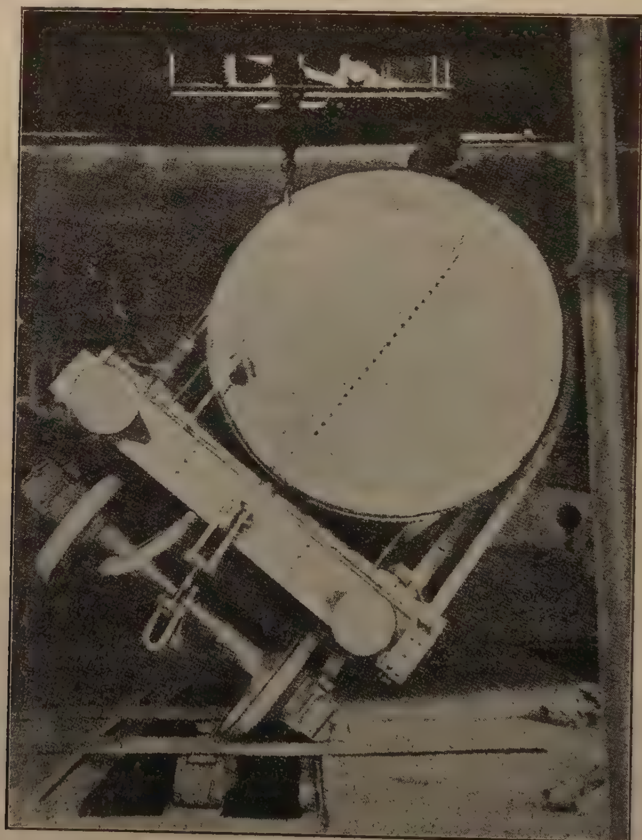

Fig. 8. — Determination of location of centre of gravity.

Rolling stock is often of very irregular form, rendering the estimation of the height of the centre of gravity somewhat complicated. Figure 8 shows a direct method, which when practicable, leaves little room for doubt as to its accuracy. The vehicle was empty, and the necessary allowance made for variation of the location when fully loaded.

[625 .61 & 656 .256]

Signalling on electric tramways,

By Roger VENTE,

CHIEF ENGINEER OF THE MARSEILLES SYSTEM.

Fig. 1 to 11, pp. 170 to 180.

(*L'Industrie des voies ferrées et des transports automobiles.*)

On railways, the running of trains over a single line is controlled by an employee specially responsible therefore. Tramways have substituted in place of the man an arrangement of signals whereby trains are warned not to enter the single line when it is already occupied by a train : this is the « block-system », an English name for which we have failed to find an equivalent (1).

In order to get away from any human intervention, and to arrive at a satisfactory automatic system, there are many essential conditions to be fulfilled : the problem can generally be stated as follows :

1. In the section between two block posts A and B, a single train only should be allowed, no matter the direction of running. It is therefore necessary that the presence of this train should be signalled at the same time to the two ends, A and B;

2. The colour of the lights must indicate the direction of running of the train moving over the single line, which makes it necessary to provide *two distinct signalling circuits,* one of which is lighted up by trains coming from end A, and the other by those coming from end B;

3. If two vehicles arrive together or soon after each other at the two ends of the single line, it must be impossible for the two signalling circuits to light up together;

4. If a vehicle after entering a section has to set back the lights should be put out from the end they lighted up;

5. The working of the signals being assured by the traction current itself, it should not be affected by voltage variations of the order of $\pm$ 25 % ;

6. Mechanical interlocking is needed such that after making good a current failure, the lighting up of the circuits

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(1) The words « block » and « block system » are often used in the wrong way. Referring to the *Electric Railway Handbook*, 1915, p. 783, the following definition will be found :

Block-system. — Method of controlling the movement of trains by which the running of a train on a section is regulated in accordance with that of one or several other trains over the same section.

Block. — Section of line over which the running of the trains is controlled in this way.

Block-signal. — Signal controlling the movement of trains on the section of line forming a block.

shall be restored exactly as before the current failed;

7. If a signal light go out whilst the single line is occupied, the other lights ought to remain alight. This is only possible if the lights are in parallel;

8. In order not to close two block system boxes through a broken signal lamp, there should be a suitable repeating signal to supplement it (such as a spare lamp or semaphore).

* * *

The whole of these requirements affect the regularity and safety of operation : they are therefore essential; moreover, they can be easily provided. Amongst suggested solutions two will be described — one American, one French — both well known on the Marseilles tramway systems. These systems actually have *ninety-six single line sections protected*, eighty-nine fitted with lamps supplied by the « U. S. Electric Signal Co. » of West Newton, and seven with lamps supplied by the « Compagnie de Signaux et d'Entreprises électriques » of Paris. We felt that an experiment of such magnitude deserved to be described.

From the point of view of the movement of trains, these two systems are identical : both have at each end of the single line a signal lamp and near them two contactors on the trolley line, one for lighting up the lamps and one for putting them out. A train entering the section protected is covered, in the rear by a white light, and in front by a red light, this latter having in addition a white witness light placed so as to be seen by the driver at the moment he passes under the contact putting it out. Finally, attached to each light there are semaphore signals repeating the light signals.

The American and French systems also do not differ as regards the various combinations of the circuits, and on one as on the other, the lighting or extinguishing of the *signalling circuits* is controlled by fugitive emissions of current flowing either through the *lighting up control circuits* or the *light extinguishing control circuits.*

Briefly, the difference between the two methods is in the kind of electro-magnet devices used to complete or break the circuits.

American method.

The essential parts of a post are three electro-magnets the armatures of which operate through three aluminium levers three circuit breakers (figs. 1 and 2).

Lighting up. — The lighting up contact of post A operates at this post the electro-magnet 2 ensuring in this way the lighting up of the white light and the sighting of the white semaphore signal : at post B the current can only return through the electro-magnet 1′, the red light and the red semaphore signal. Inversely, if the operation had begun at post B, the contact at this post would have operated the electro-magnet 2′ of post B and the electro-magnet 1 of post A.

These two conflicting operations ought never to be released at the same time. — Any possibility of their occurring together is prevented by connecting levers 1 and 2 by a spring so that the circuit breakers 1 and 2 can be both closed, but never open at the same time; in other words, the opening of one of these circuit breakers ensures or maintains the other being closed.

In addition to the spring connection of these two levers, they are also interlocked : at the moment a failure of current occurs the current breaker 2 is kept closed, as it can only be released from the lock by means of the lever 1 (fig. 3).

The lighting up current only lasts a moment, but the permanent holding current continuing to flow through the magnets, the circuit is kept closed until

the moment a suitable current impulse breaks it.

Extinguishing the lights. — Under the action of the extinguishing contact of post B, the electro-magnet 3′ of this post breaks the signalling circuit (magnet 2, line 1, magnet 1′). The current returns by the extinguishing control circuit, the magnet 1 of post A and the red light of this same post, which glows for a short time before the general extinction. Inversely, for a movement started at B, the magnet 3 of A would have broken the other signalling circuit (magnet 1, line 1, magnet 2′).

The light extinguishing circuits — as the lighting up circuits — are only traversed by short impulses equal in duration to that of the operation of the contacts, whilst the signalling circuits are lighted up during the whole time the single line is occupied.

Purchase cost. — The pre-war price was originally about 2 130 francs for two posts : it was subsequently reduced to 1 740 francs.

In 1922 it would have cost 12 000 francs for an American set of fittings for a block equipment with semaphores. The « Compagnie de Signaux et d'Entreprises électriques » at this time submitted an alternative proposal.

French solution.

Like the American, the French signal consists of three electro-magnets, but two of these have a common core, and instead of three there is only one rocking lever shaped like the beam of a balance (figs. 4 and 5).

Lighting up. — Under the action of the lighting up contact of post A, the magnet 1 at this post inclines the rocking lever towards the left. In this position the vertical spindle of the lever closes the circuit of the white light of post A, and at the same time puts it in series with the magnet 3′ and the red lamp of post B. *In this latter, the magnet 3′ holds the lever inclined to the right.* Subsequently it is impossible for a train entering by post B to thereby cause the lever in this box to swing over to the left and set up the lighting up impulse.

To sum up, at each post the lever can incline in one or the other direction, but it cannot remain in an intermediate position. In order to make this certain, the vertical spindle of the lever has been fitted with a spring which is intended to make the lever incline over to the left: a locking device is provided in the opposite position which holds the lever in place in the event of a current failure (fig. 6).

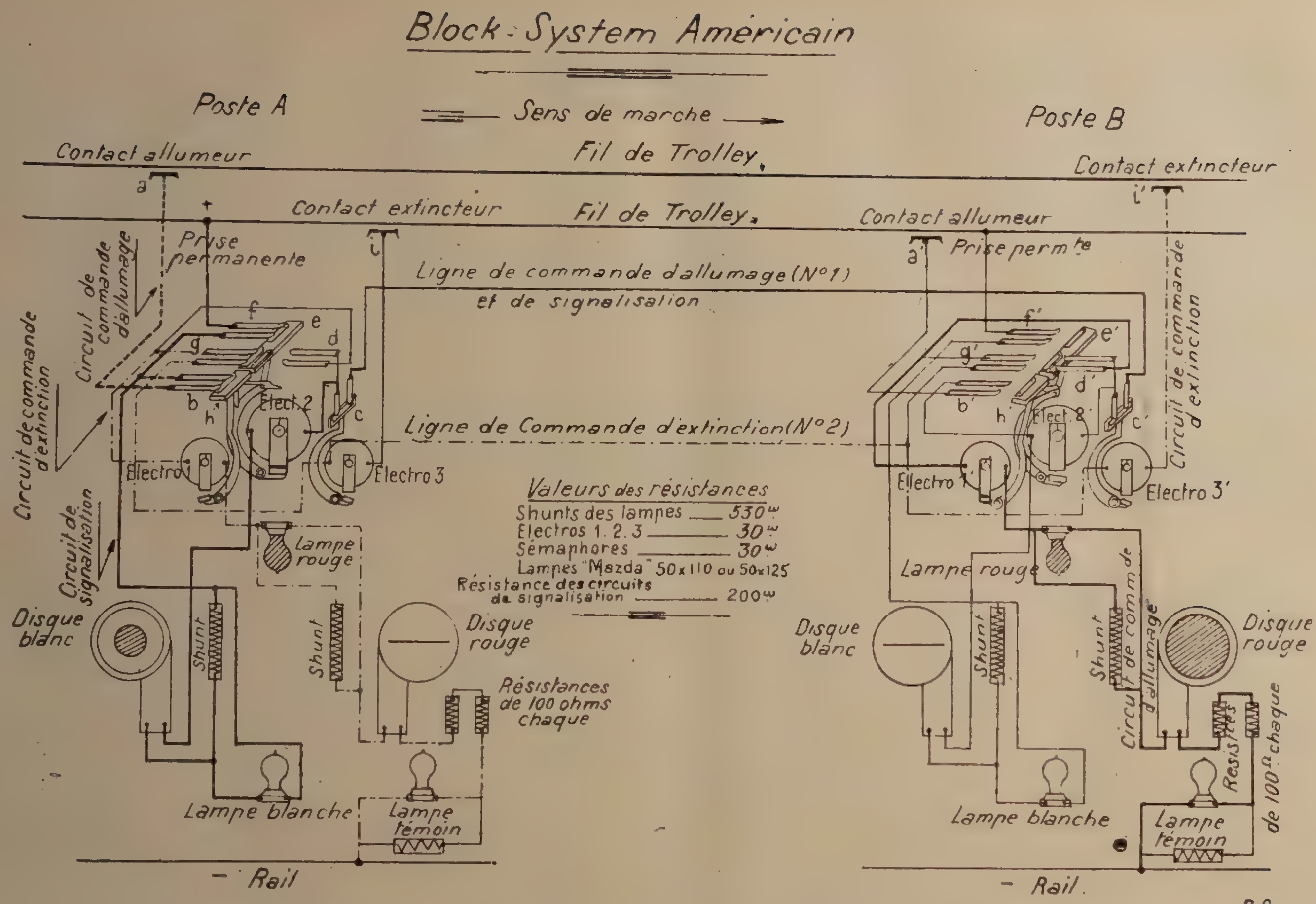
Extinction. — A train leaving by post B sends by the extinguishing contact an impulse to the magnet 2 of box A which restores the lever to the right hand position, and at the same time breaks the signalling circuit.

Purchase cost. — With the various improvements that we have made in the Signal Company's apparatus, the purchase price for the complete equipment of a block with semaphores amounts to 6 000 francs, which is just half the price of American material. As an appendix, a cost sheet including the accessories and labour charges is attached (appendix No. 1).

American apparatus.

1. *Simultaneous entrance into section.* — The American signals have worked extremely well ever since the electric operation of the Marseilles system was started. The only cases in which they were found wanting are those of « *trams entering the section at the same time* », and such coincidences are less improbable than would appear at first sight.

As a matter of fact, when two drivers are waiting at the two ends of the single



DESCRIPTION OF THE CIRCUITS.

Lighting up control circuit. — Contactor a, contacts b, half contact f, white light, white disc, magnet 2, contacts c, line No. 1, contacts c', contacts d', magnet 1', red light and disc, resistances, rail.

Signalling circuits. — Permanent current collector, contacts f, thereafter a circuit mixed up with the former.

Light extinguishing circuit. — Contactor i', magnet 3', line No. 2, contacts a, magnet 1, red light, red disc, resistances, rails. (Three similar circuits for the opposite direction of running.)

Fig. 1.

Explanation of French terms in figure 1.

Block system américain	= *American block system*	Electro	= Electro magnet.
Poste A	= A post.	Disque blanc	= White disc.
Poste B	= B post.	Disque rouge	= Red disc.
Contact allumeur	= Lighting up contact.	Lampe rouge	= Red light.
Sens de marche	= Direction of running.	Lampe blanche	= White light.
Contact extincteur	= Extingu. shing contact.	Lampe témoin	= Witness light.
Fil de trolley	= Trolley wire,	*Valeurs des résistances*	= *Value of resistances.*
Prise permanente	= Permanent current collector.	Shunts des lampes 530 ω	= Lamp shunts, 350 ohms.
Ligne de commande d'allumage (n° 1) et de signalisation	= Lighting up and signalling control line.	Electros 1, 2 et 3, 30 ω	= Nos. 1, 2 and 3 electro magnets, 30 ohms.
Ligne de commande d'extinction (n° 2)	= Light extinguishing control line.	Sémaphores, 30 ω	= Semaphores, 30 ohms.
Circuit de commande d'allumage	= Lighting up control circuit.	Lampes « Mazda » 50 × 110 ou 50 × 125	= « Mazda » bulbs 50×110 or 50×125.
Circuit de commande d'extinction	= Light extinguishing control circuit.	Résistances des circuits de signalisation, 200 ω	= Resistances of signalling circuits, 200 ohms.
Circuit de signalisation	= Signalling circuit.	Résistances de 100 ohms chaque	= Resistances of 100 ohms each.

line for the line to be clear, each approaches as near as he can to the contactor so as to have priority. Although the time lag of the magnets is two-tenths of a second, it may happen that the two impulses may be at a less interval and neutralise one another. Under these conditions the lamps do not light up.

This defect has been overcome by instructing the drivers to remain a certain distance in front of the contactors, namely 10 m. (33 feet) if they see a red light, and 1 m. (3 feet) if they see a white light.

2. *Voltage variations.* — When the voltage drops below 350 — as sometimes occurs on suburban lines which is just where such single lines are found — the American signals stop working.

This defect has been cured by replacing the carbon filament bulbs with metallic filament 50-candle power bulbs, of commercial manufacture (Mazda). These lamps having much less resistance cold than hot, allow the control current emissions to pass with sufficient intensity. Their fragility has not been found to be greater than that of the carbon lamps.

3. *Contactors.* — The American contactors are fitted directly on the trolley wire surrounding it with a forked pedal which is moved each time the trolley wheel passes. The pedal itself controls the closing of a circuit breaker, the opening of which is delayed 4 to 5 seconds by means of a toothed wheel with which a delay action ratchet arm gears (fig. 7).

The upkeep of these contactors being costly, the Company made up a very substantial pattern, without the retarding device, without any failure of the magnets resulting. At first any shaking of the trolley wires was enough to make this pattern work, but fitting additional springs stopped this excessive sensitiveness (fig. 8).

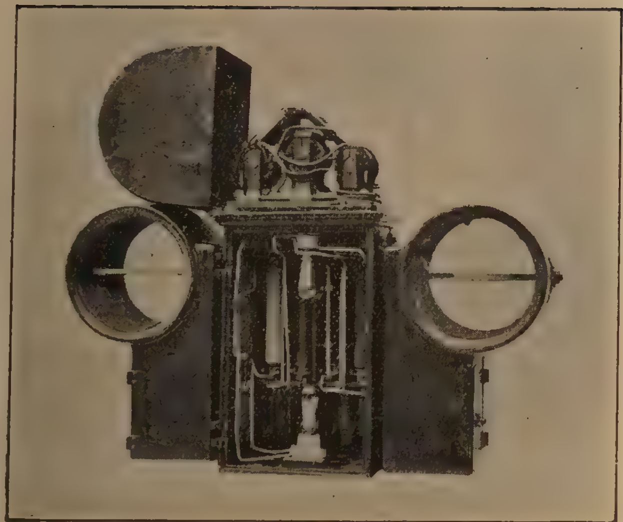


Fig. 2.

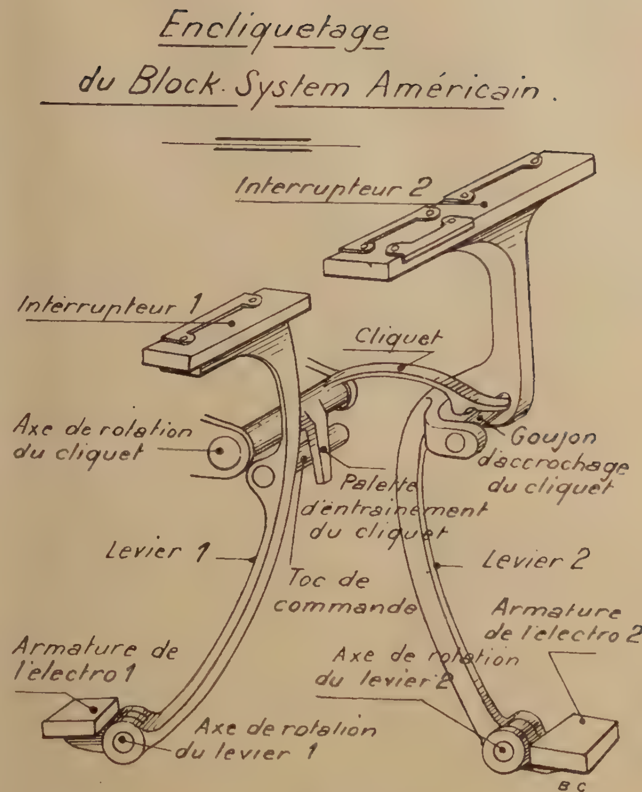


Fig. 3.

Explanation of French terms in figure 3 : Armature de l'électro 1 (2) — Core of No. 1 (No. 2) magnet. — Axe de rotation du cliquet = Pin about which ratchet rocks. — Axe de rotation du levier 1 (2) = Pin about which No. 1 (No. 2) lever rocks. — Cliquet = Ratchet. — Encliquetage du block-system américain = Ratchet gear of American block system. — Goujon d'accrochage du cliquet = Stud on which ratchet hooks — Interrupteur 1 (2) = Breaker No. 1 (No. 2). — Levier 1 (2) = No. 1 (No. 2) lever. — Palette d'entraînement du cliquet = Arm by which ratchet is moved. — Toc de commande = Driving pin.

4. *Semaphores.* — The Marseilles system decided in 1924 to fit with semaphores 94 lamps of American origin not so fitted : it was therefore a question of purchasing 188 semaphores. The type of the « U. S. Electric Signal Co. » was offered at 1 200 francs : it consists of a metal disc 10 inches in diameter, controlled by a Galle chain coupled to the end of the armature of an electro-magnet (fig. 9).

At the same time the « Compagnie de Signaux et d'Entreprises électriques » quoted us in connection with the lamps ordered from them, for « Banjo », semaphores with a cloth disc, at the price of only 500 francs. The Marseilles system preferred however to design a pattern on the following lines : as with the American semaphore, a 20 cm. (8-inch) diameter disc oscillates about a horizontal pin which carries a helicoidal sector forming the armature of the electro-magnet. When the magnet is energised the sector turns so as to offer its largest section and give a less interferric space : there is then a magnetic coupling replacing the mechanical coupling by chain of the American semaphore. We get in this way what Silvanus Thompson called « an electro-magnetic cam » (fig. 10).

A variation of voltage test showed that the Banjo ceased to work at 350 volts, whereas the American semaphore and the Marseilles pattern still functioned at 200 volts, and the latter could be made for 425 francs.

French apparatus

1. *Contacts.* — The French lamps have only *two* moving contacts, whereas the American have ten, so that the upkeep of the former is cheaper. On the other hand, the French makers had to replace the sliding contacts on carbon by pressure contacts which had been already tested out on foreign material.

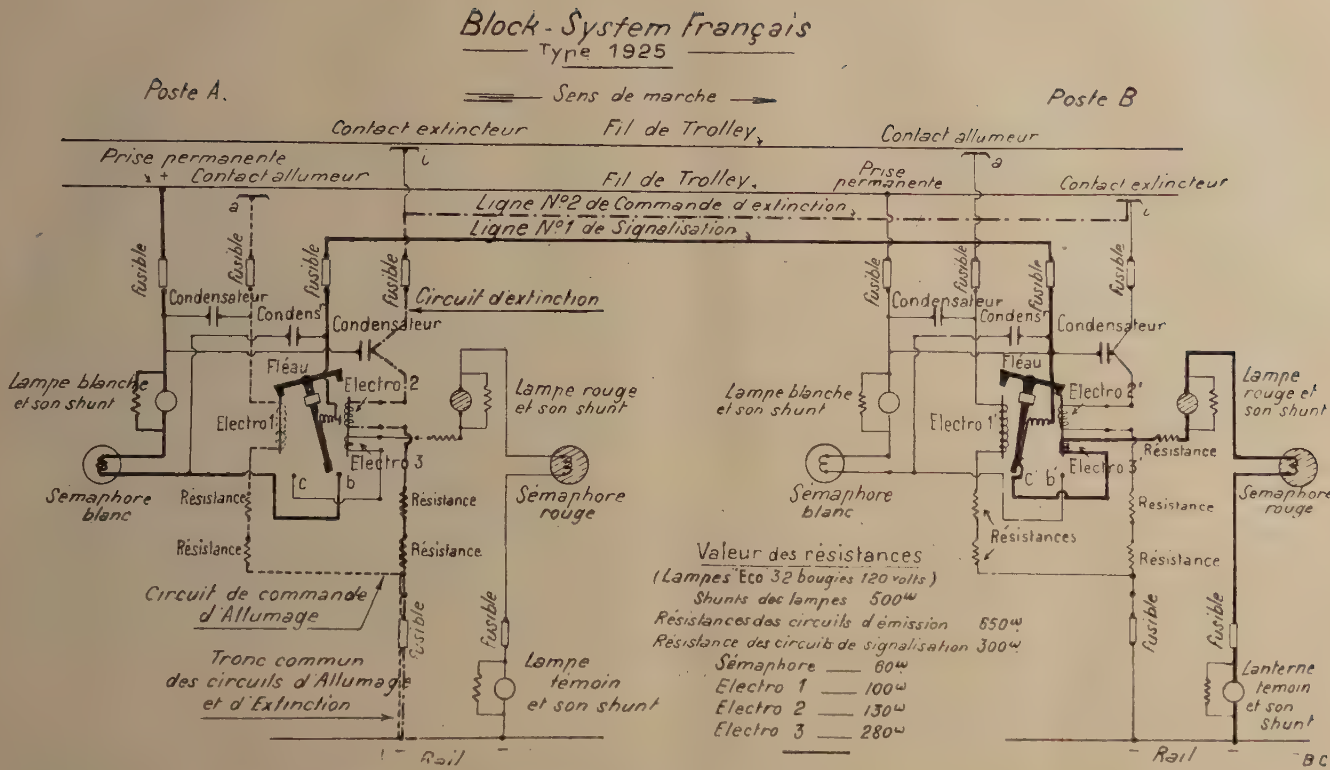
2. *Simultaneous entrance into section.* — In offering its apparatus, the Compagnie de Signaux et d'Entreprises électriques pointed out that its apparatus would not meet the case of simultaneous entrance into section, with the aggravating result that this false manœuvre would immobilise the arms of the lamps and would need an extinguishing control to put things in order.

These difficulties, which our operating instructions had already met in the case of the American apparatus, did not prevent our proceeding with the matter.

3. *Want of balance.* — The rocking lever ought to have two possible positions only : one leaning towards the right, and the other towards the left. Now, owing to the voltage drop on the Marseilles system, — or even when vehicles pass too quickly past the contacts — locking does not take place and, after the emission of the fugitive control current, the lever would fall again into an intermediate position. In this case, the lights go out and the vehicle would not be protected. For this reason we suggested to the maker the use of a light spring which restores the lever to its position of rest in the case of all failures of the ratchet gear.

With this modification, the French arrangement could not give any ambiguous indication *even if the ratchet is out of order* — as then the signal remains lighted up — *even when the spring breaks* — the signal then remaining out, as the current passes through this spring. On the other hand, in the American arrangement a broken ratchet could falsify the signal indications and nothing would at first sight indicate the failure.

4. *Contactors.* — The contactors of the Compagnie de Signaux, which were found to be too weak and too bulky, have been replaced by our former pattern : as this pattern has no delay action



Description of the circuits.

Lighting up control circuit. — Contactor 1, magnet 1, resistances, rail.

Signalling circuit. — Permanent current collector, white light, white semaphore, contact *b*, rocking lever, line 1, rocking lever, contact *c'*, magnet 3', resistance, red light, red semaphore, witness light, rail.

Lights out circuit. — Contactor *i'*, line No. 2, magnet 2, resistances, rail.

3 identical circuits for the opposite direction of running.

Fig. 4.

Explanation of French terms in figure 4.

Block system français, type 1925	=	*French block system, 1925 pattern.*
Poste A	=	A post.
Sens de marche	=	Direction of running.
Contact extincteur	=	Light extinguishing contact.
Fil de trolley	=	Trolley wire.
Contact allumeur	=	Lighting up contact.
Prise permanente	=	Permanent current collector.
Ligne n° 2 de commande d'extinction	=	No. 2 light extinguishing line.
Ligne n° 1 de signalisation	=	No. 1 signalling line.
Fusible	=	Fuse.
Condensateur	=	Condenser.
Circuit d'extinction	=	Lights out circuit.
Electro	=	Magnet.
Fléau	=	Rocking lever.
Lampe témoin et son shunt	=	Witness light and shunt.
Lampe blanche et son shunt	=	White light and shunt.
Lampe rouge et son shunt	=	Red light and shunt.
Sémaphore blanc	=	White semaphore.
Sémaphore rouge	=	Red semaphore.
Résistance	=	Resistance.
Rail	=	Rail.
Circuit de commande d'allumage	=	Lighting up circuit control.
Tronc commun des circuits d'allumage et d'extinction	=	Section common to lighting up and extinguishing circuits.
Valeurs des résistances	=	*Value of resistances.*
(Lampes « Eco » 32 bougies, 120 volts)	=	« Eco » bulbs, 32-candle power, 120 volts.
Shunts des lampes, 500 ω	=	Lamp shunts, 500 ohms.
Résistances des circuits d'émission, 650 ω	=	Resistance of propagation circuits, 650 ohms.
Résistance des circuits de signalisation, 300 ω	=	Resistance of signalling circuits, 300 ohms.
Sémaphore — 60 ω	=	Semaphore — 60 ohms.
Electro 1 — 100 ω	=	Magnet No. 1 — 100 ohms.
Electro 2 — 130 ω	=	Magnet No. 2 — 130 ohms.
Electro 3 — 280 ω	=	Magnet No. 3 — 280 ohms.

device, a reduction of the self-induction of the electro-magnets and an increase in the intensity of the control current was necessary. This resulted in continuous arcs at the contactors which had to be stopped by inserting condensers of a tenth of a microfarad capacity across the terminals. (Three condensers per lamp, one for each of the circuits). We also had to introduce resistances in the circuits to shunt the lamps or to reduce the strength of the current. These resistances were made of a nickel chrome wire 0.25 mm. (0.0098 inch) diameter wound on an asbestos cord 3 mm. (0.118 inch) in diameter, mounted on grooved porcelain plates.

5. *Boxes.* — The Compagnie de Signaux proposed to divide the apparatus between two boxes (see figure 11 of a block supplied to the State Railways Administration for the Olympic Games):

A lamp box placed on the top of a post so as to be visible;

A resistance box placed at man height so as to be readily accessible.

We required a single box as in the American pattern, and asked for the electro-magnets to be carried on a slate slab instead of on wood as originally proposed. Modified in this way the French apparatus shewed itself to be superior to the American as regards simplicity, whilst having the same total weight [123 kgr. (271 lb.) whereof 59 kgr. (130 lb.) for the lamp and 32 kgr. (70 1/2 lb.) for the semaphore] and being equally strong.

Maintenance of signals.

During the year 1926 the Marseilles system recorded 775 failures in its block system. A detailed list of the defects is attached as an appendix to the annual report on upkeep (appendix No. 2). At first this number seems high, but will be found moderate when it is compared with the number of sets installed.

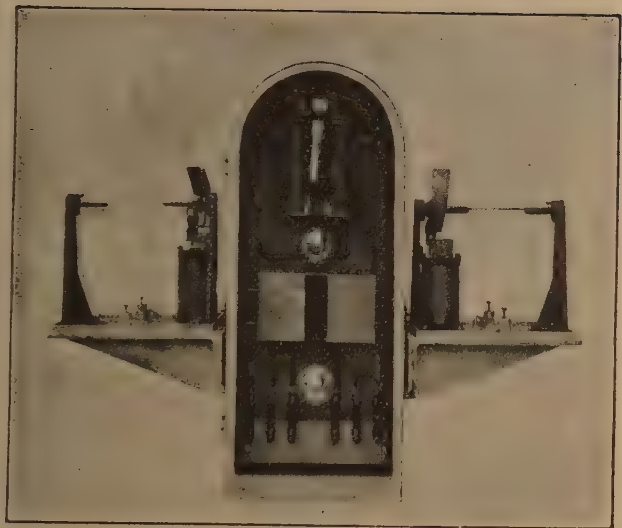


Fig. 5.

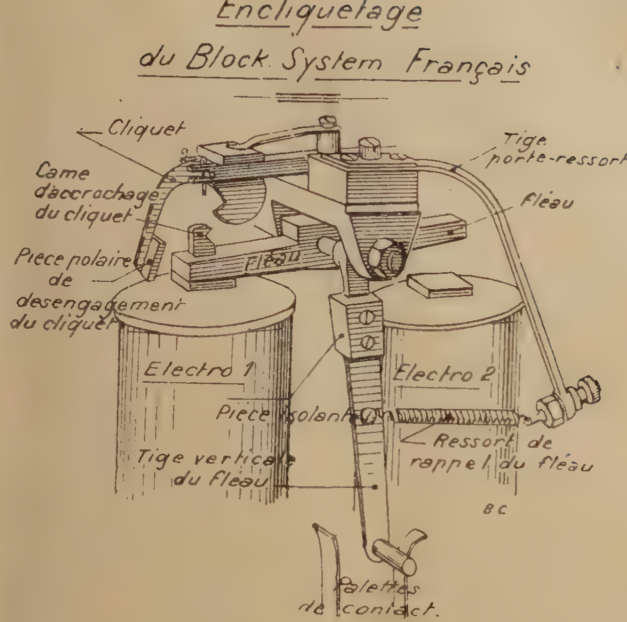


Fig. 6.

Explanation of French terms in figure 6 :

Came d'accrochage du cliquet. . . .	=	Ratchet holding cam.
Cliquet	=	Ratchet.
Electro 1.	=	Electro-magnet 1.
Encliquetage du block system français.	=	*Ratchet gear of French block system.*
Fléau.	=	Rocking lever.
Palettes de contact	=	Contact arms.
Pièce isolante.	=	Insulator.
Pièce polaire de désengagement du cliquet	=	Ratchet pole releasing plate.
Ressort de rappel du fléau.	=	Rocking arm return spring.
Tige porte-ressort.	=	Spindle carrying spring.

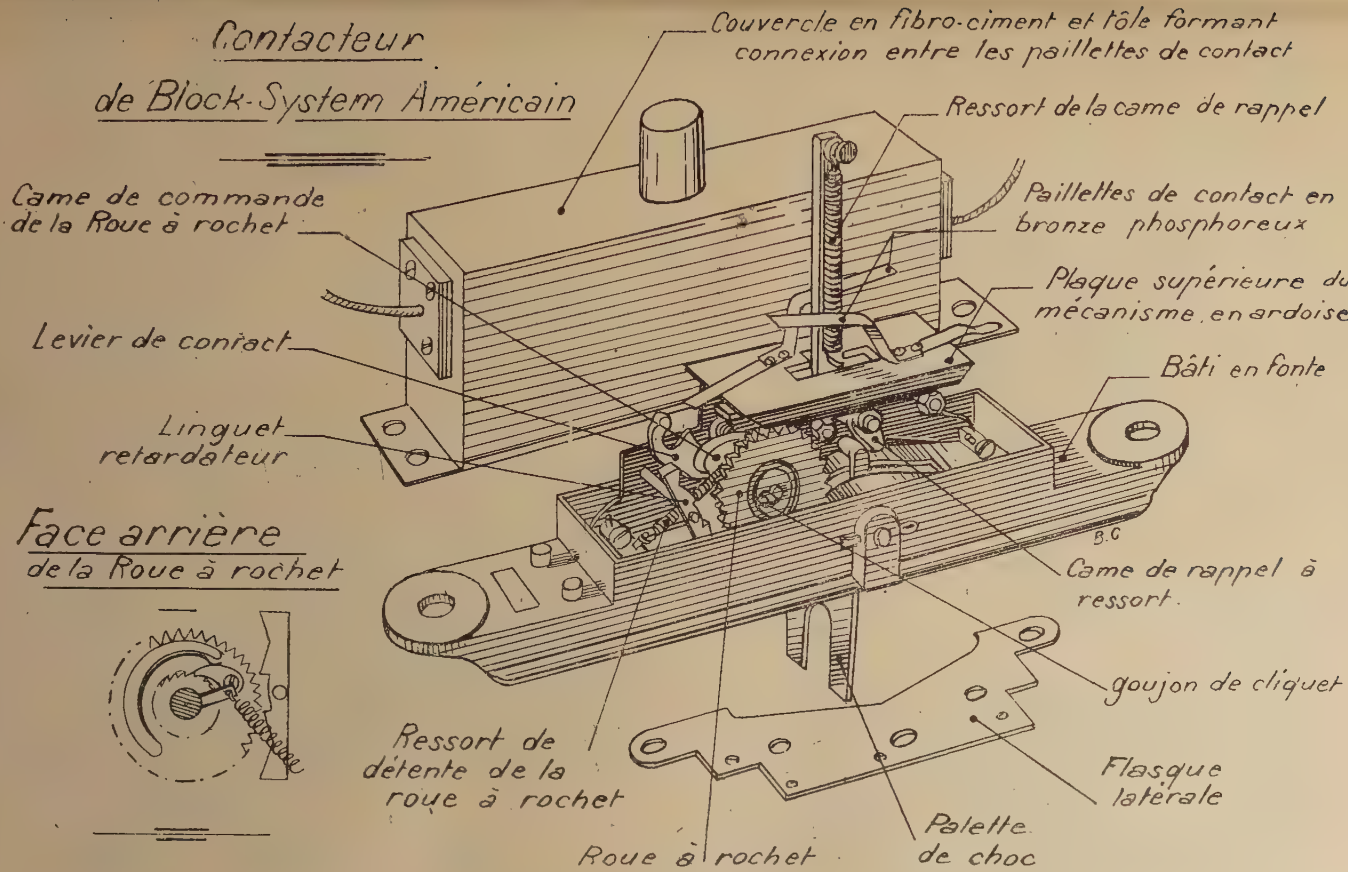


Fig. 7.

Explanation of French terms : Bâti en fonte = Cast iron frame. — Came de commande de la roue à rochet = Control cam of the ratchet wheel. — Came de rappel à ressort = Spring return cam. — *Contacteur de block-system américain* = *American block-system contactor.* — Couvercle en fibro-ciment et tôle formant connexion entre les paillettes de contact = Fibrous concrete metal cover connecting the contact blades. — *Face arrière de la roue à rochet* = *Back face of the ratchet wheel.* — Flasque latérale = Side plate. — Goujon de cliquet = Ratchet pin. — Levier de contact = Contact lever. — Linguet retardateur = Delay action pawl. — Paillettes de contact en bronze phosphoreux = Contacts in phosphor bronze. — Palette de choc = Striking arm. — Plaque supérieure du mécanisme en ardoise = Top plate of the gear, of slate. — Ressort de la came de rappel = Spring of the return cam. — Ressort de détente de la roue à rochet = Releasing spring of the ratchet wheel. — Roue à rochet = Ratchet wheel.

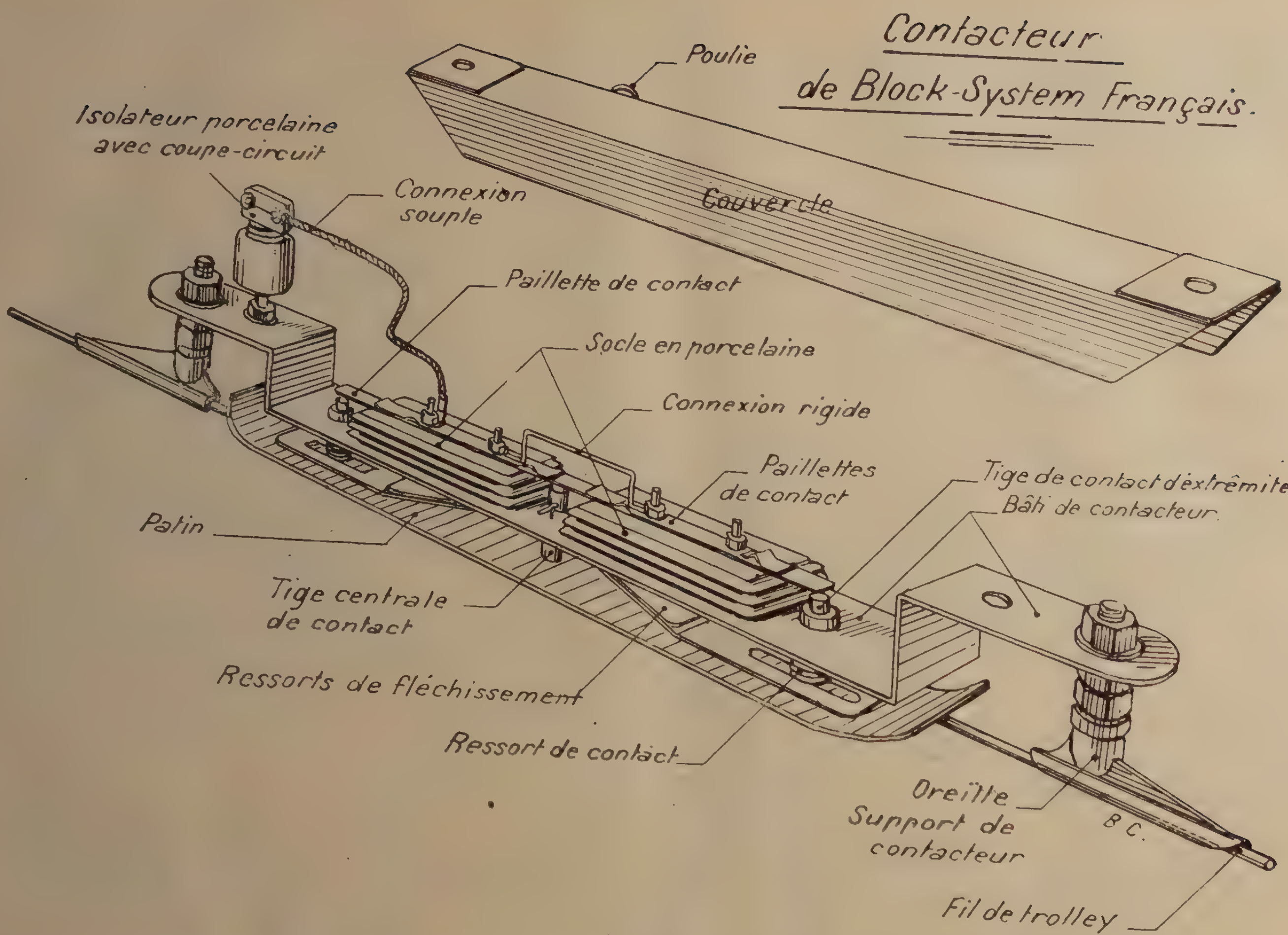


Fig. 8.

Explanation of French terms. *Contacteur de block system français* = *French block system contactor*. — Bâti de contacteur = Contactor frame. — Connexion rigide = **Rigid connection.** — Connexion souple = Flexible connection. Couvercle = Cover. — Fil de trolley = Trolley wire. — Isolateur porcelaine avec coupe-circuit = **Porcelain insulator with fuse.** — Oreille support de contacteur = Lug carrying contactor. — Paillettes de contact = Contacts. — Patin = Shoe. — Poulie = Wheel. — **Ressort de contact = Contact spring.** — Ressorts de fléchissement = Springs to take up any deflection. — Socle en porcelaine = Porcelain block. — Tige centrale de contact = Centre contact spindle. — Tige de contact d'extrémité = End contact spindle.

de Block-System français

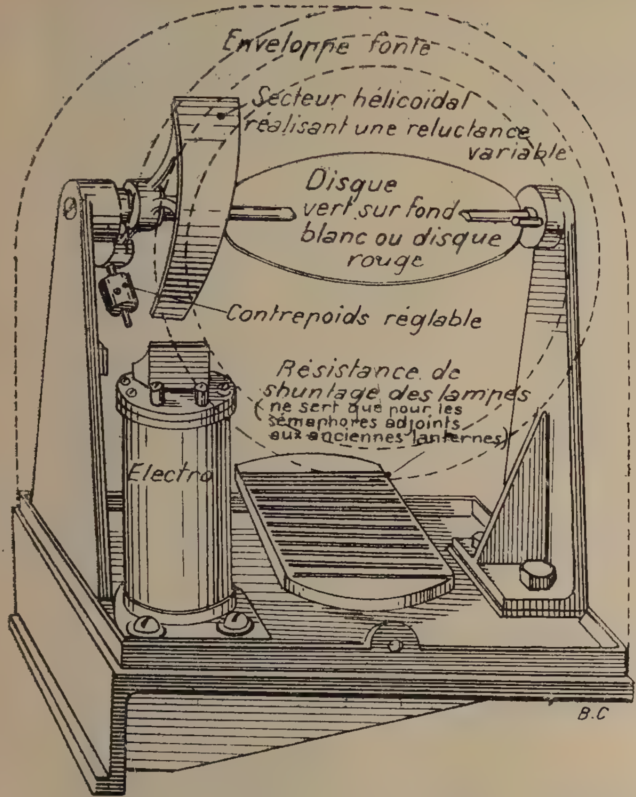


Fig. 9.

de Block System Américain.

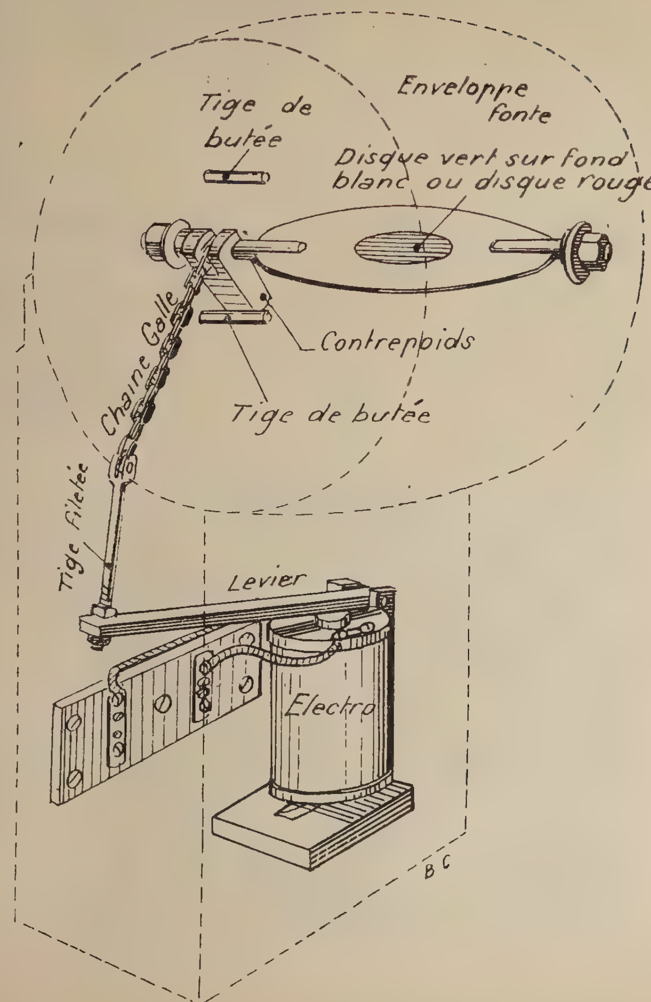


Fig. 10.

Explanation of French terms in figures 9 and 10:

Chaine Galle = Galle chain. — Contrepoids = Counterbalance weights. — Contrepoids réglable = Adjustable counterbalance weight. — Disque vert sur fond blanc ou disque rouge = Green disc on a white ground or a red disc. — Electro = Electro magnet. — Enveloppe fonte = Cast iron casing. — Levier = Lever. — Résistance de shuntage des lampes (ne sert que pour les sémaphores adjoints aux anciennes lanternes) = Shunting resistance of the lamps (only used with semaphores fitted to old lamps). — Secteur hélicoïdal realisant une reluctance variable = Helicoidal sector giving a variable magnetic reluctance. — Tige de butée = Stop spindle — Tige filetée = Screwed pin. — *Sémaphore de block-system américain = American block-system semaphore. — Sémaphore de block-system français = French block-system semaphore*

Fig. 11.

It can be taken that for each failure the ladder truck was away on an average two hours, that is, a total of 1 550 hours a year. It is therefore necessary to have a ladder truck almost permanently allotted to this work, and as it costs 25 francs an hour, it will be appreciated how desirable it is to improve the signal service both from the financial point of view as from that of regular working.

In order to train the signal repair staff, at the shop two lamps were fitted up on which all defects could be demonstrated and repaired as desired.

In addition, attention has been given to suppressing the causes of the failures: the lamps and the contact strips are renewed methodically after a certain length of use : the lamps are shunted and the fuses of the contactors are carried on the neighbouring post: the signal lines are carried underground on roads bordered by trees, and finally the brackets carrying the lamps and the contactors have been strengthened.

Conclusions.

The American and French signals work in a regular manner on the Marseilles systems with an intensity of passing vehicles reaching 300 and even, in one case, 650 per day.

The operating rules we have drawn up have enabled us to avoid all accidents when they have been correctly observed (appendix No. 3).

These results are satisfactory, and when we shall have completed certain alterations, to the fittings, suggested by practical experience, it appears to us that the cases of the signals failing to work will be reduced to a minimum below which it would not be possible to go.

We would point out in ending an interesting article on the subject of the Block System published by Messrs. Sire and Boissel (1). The authors criticise the use by tramway companies of red, white and green lights, which is not in agreement with the « Signal Code ». They propose :

Red winking signals indicating line occupied;

Luminous arrows indicating the direction of movement of the train on the section.

We are not aware that this arrangement has been made use of anywhere.

To terminate this article, it may be noted — *si parva licet componere magnis* — that the block signals are the humble ancestors of the automatic substations. This flattering parentage reflects some lustre on them and justifies our desire to pay honour to them.

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(1) *L'Ingénieur-Constructeur*, July 1925. Various schemes of manually operated block systems and a description of multiple recording block systems will be found in this article.

APPENDIX No. 1.

Cost of installing two block signal posts.

Type « Compagnie des Signaux ».

A. — For one set.

Material :		Francs.	Francs.
Lamps supplied by the « Compagnie des Signaux »	2	1 590.00	3 180.00
Condensers and bulbs		...	300.00
Semaphores.	4	425.00	1 700.00
Contactors	4	200.00	800.00
Witness lamps.	2	100.00	200.00
Frames for block lamps with semaphores . . .	2	200.00	400.00
Ironwork at contact points	4	135.00	540.00
Pull-offs	20	6.00	120.00
Insulated wire 20/10	100 m. (109 yards)	1.20	120.00
Clips for securing block lamps	2	50.00	100.00
Clips for securing witness lamps	2	85.00	170.00
			7 630.00
Labour :			
Working days of gang including ladder truck . .	4	200.00	800.00

B. — Per kilometre (0.621 mile) of track.

Material :		Francs.	Francs.
Wire 30/10 [63 kgr. per kilometre (223.5 lb. per mile)]	2 000 m. (2 187 yards)	1.50	3 000.00
Clips for insulators	70	35.00	2 450.00
Insulators	70	6.00	420.00
			5 870.00
Labour :			
Working days of gang including repair truck . .	4	200.00	800.00

SUMMARY.

	For one set.	*Per kilometre (0.621 mile) of track.*
	Francs.	Francs.
Installation : Material	7 630.00	5 870.00
Labour	800.00	800.00
Various and contingencies	1 390.00	830.00
	9 820.00	7 500.00

APPENDIX No. 2.

Annual report on maintenance of the block system signals on the Marseilles tramway sytems.

The material used in signalling the Marseilles system is not of one pattern but includes :

80 American sets . . . { 3 sets of A_1 pattern lamps; 5 sets of B_1 pattern lamps; 31 sets of C_1 pattern lamps; 50 sets of G_1 pattern lamps } made by the U. S. Electric Signal Co. of West Newton.

7 French sets. . . . . 7 sets of lamps supplied by the « Compagnie des Signaux » of Paris.

The American apparatus was purchased at various times prior to 1924. The French apparatus dates from 1925.

In addition, paralleling the lamps and adding semaphores is still being carried out, only 50 sets having been altered.

Subject to these reserves, we are all the same able to establish averages which are of interest.

* * *

775 defects have been made good which, as there are 96 block sections, represents about 8 failures per block per annum.

These defects were as follows :

DEFECTIVE PART.	NUMBER OF DEFECTS AND NUMBER OF SETS OF APPARATUS IN USE.	AVERAGE.
1. Bulbs	180 for 576 in use.	Average life of bulbs : 3 years.
2. Contactors.	137 for 384 in use.	1 per contactor every 3 years.
3. Overhead contactor fuses .	132 for 384 contactors in use.	1 per contactor every 3 years.
4. Aerial lines	97 for 82 sets and about 100 km. (62 miles) of twin wire signal line.	1 per set every 10 months.
5. Armoured cables	6 for 14 sets with underground cables.	1 per set every 2 years.
6. Light fuses	70 for 192 lights and 5 fuses per light (960 fuses).	1 per light every 3 years.
7. Contact strips	70 for 192 lights and a total of 1 804 contact strips.	1 per light every 3 years.
8. Electro-magnets	31 for 192 lights and a total of 776 magnets.	1 per light every 6 years.
9. Resistances	18 for 192 lights and a total of 592 resistances.	1 per light every 10 years.
10. Contacts of contact strips .	15 for 531 contacts.	No average.
11. Insulators	7 for about 9 000 insulators.	No average.
12. Return connections to the rails	5 for 192 lights.	No average.
13. Control levers	3 for 534 levers.	No average.
14. Ratchet devices	3 for 178 ratchets of the American signals.	No average.
15. Bulb caps	2 for 576 bulbs.	No average.

NOTES ON THE DEFECTS :

1. Defects of the bulbs will diminish to a large extent when they are all in parallel, which is being done as the semaphores are fitted. The same thing will occur in the case of the overhead fuses when Gardy insulators fastened to the arms are substituted.

2. Nine-tenths of the defects on the overhead lines are found at the point of arrival at the contactors, and at the permanent connection to the feeders, and are most frequently caused by the trolley-pole coming off the line.

3. Most of the defects in the electro-magnets were caused by the many storms in 1926; which was also the case with those in the armoured cables.

4. Defects in the ratchet devices of the American block apparatus were very rare : two per annum. This is fortunate because this defect puts the signal out of action.

Methodical upkeep : Each signal post should be inspected at least once a year to adjust the mechanism and renew worn or defective parts.

The proper working of the signals presupposes that the 600 posts carrying the lamps are in good order; and also the stays supporting the contactors and the curreut collectors : a broken cross stay or a loose support is sufficient to deflect a contactor and cause the trolley arm to derail when passing it.

Appendix No. 3.

Movement of vehicles over single lines fitted with block system signals.

When on entering a single line covered by block signals, the driver sees before him a red light, he stops with the trolley pole about 10 m. (33 feet) from the lighting up contact : if he should see a white light he stops with the trolley about 1 m. (3 feet) from the contact.

If the current fail, the driver takes care not to run under the lighting up or extinguishing contacts in order not to upset the lamps.

When the trolley pole comes off the trolley wire just after passing under a lighting up contact, the driver stops the vehicle and the conductor of the motor vehicle makes sure that the disturbance of the overhead line has not caused the signal lights to go out. If the trolley come off some way from the lighting up contact, the driver continues his journey, making the conductor of the motor vehicle protect him 50 m. (164 feet) ahead.

Should a block system signal not act, the driver continues his journey, the conductor of the motor vehicle going 50 m. (164 feet) ahead to protect him. He warns all the drivers he passes and notifies the first controller he meets that the signal is out of order : the latter advises as quickly as he can the repair gang and visits the place where he makes the following arrangements :

1. *On lines with little traffic* (20 to 40 minutes), arrange a service with fixed crossings, *i. e.* to cross vehicles at fixed points.

2. *On lines with heavy traffic* to establish a service by train staff.

The chargehand of the repair gang ordered to make good the defect protects the repair truck by placing on both sides of it a red flag at a sufficient distance for the drivers to sight it before reaching the place where repairs are being made. These flags are placed on the line : not on the trolley.

As soon as the repairs have been done, the controller (or in his absence, the chargeman of the repair gang) makes the following arrangements :

a) *When the service is by fixed crossing places :*

The repair truck does not leave until after a vehicle has passed *in each direction* and the controller (or chargeman) advises the drivers of these vehicles that the service is again working normally.

b) *When working with the train staff :*

The staff is withdrawn by the controller or chargeman of the repair gang who do not leave the place until a train has passed *in both directions* and warn the drivers of these trains that the service is again normal.

It is against the regulations for two vehicles travelling in the same direction to pass one after the other on to a single line protected by a block system signal, unless on the order of a controller who takes on his own responsibility the following precautions :

1. The second vehicle only runs into the section if the conductor and driver of the first vehicle have been warned that another vehicle is following after them;

2. The driver of the first vehicle stops before running under the extinguishing contacts, and the conductor of the motor vehicle pulls the trolley so as not to extinguish the lights.

It is the second vehicle that extinguishes the lights.